

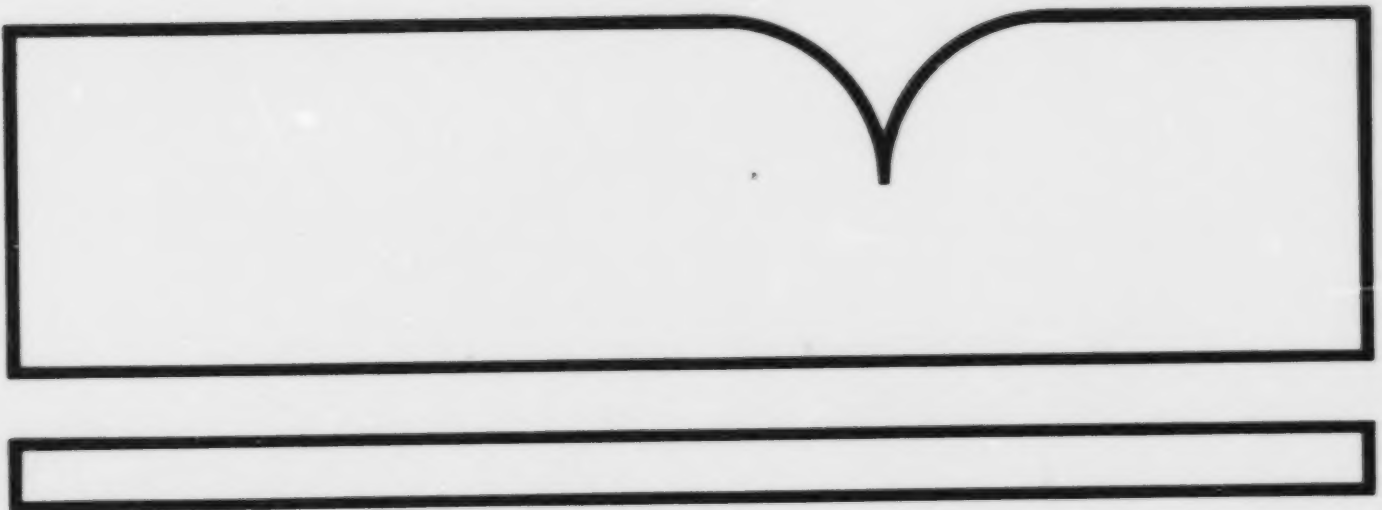
Regional Air Pollution Study: Effects of
Airborne Sulfur Pollutants on Materials

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Effects of Airborne Sulfur Pollutants on Materials

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Effects of Airborne Sulfur Pollutants on Materials

by

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ABSTRACT

This report discusses the results obtained between October 1974 and March 1977 in an exposure study at nine test sites in St. Louis, Missouri, under Task Orders Nos. 26 and 112 as part of the Regional Air Pollution Study (RAPS). Samples of galvanized steel, weathering steel, Al 2014 and 7079 tensile samples, silver, marble, nylon and two types of house paint have been exposed for various lengths of time. Atmospheric data which include wind speed and direction, temperature, relative humidity (RH), total sulfur, SO_2 , H_2S , O_3 , NO_x , total hydrocarbon, total suspended particulates, sulfate and nitrate have been collected at each exposure site under the Regional Air Monitoring System (RAMS).

For galvanized steel and weathering steel, four different sets have been exposed in order to study the effect of the atmospheric conditions at first exposure on subsequent corrosion behavior. For galvanized steel a pronounced effect of time of first exposure was observed, while the corrosion behavior of weathering steel did not seem to depend on the seasonal effects. The corrosion kinetics of galvanized steel were shown to be different for first exposure in the fall and winter as compared to first exposure in the spring or summer, where linear corrosion kinetics and lower corrosion rates were observed.

House paint showed discontinuous corrosion behavior with the highest corrosion rates being observed between October 1974 and January 1975, and between April and October 1975. Exposure to the south was more corrosive than exposure to the north for both latex and oil base paint. The integral corrosion rates for latex base paint were higher than those for oil base paint.

The corrosion rate of marble decreased with time at all sites.

Tarnishing of silver plated samples was measured by the reflectance loss and by an electrochemical technique. At some sites 50% reflectance loss occurred after 3 months exposure.

All nine samples of Al 7079 at 25 Ksi failed in less than 255 days, while complete failure at 15 Ksi occurred between 277 and 630 days. At one site (#120) one sample remained unbroken. For Al 2014 more scatter in the time-to-failure was observed. At sites #103 and 120 all samples at 45 Ksi failed in 66 and 83 days, respectively, while one sample remained unbroken after 30 months at each of sites #112 and 115. At 25 Ksi, all samples cracked only at sites #105 and 108.

The tests with nylon filament which fails when in contact with acid drops proved to be inconclusive.

The pollution levels in St. Louis were found to be rather low. The quarterly SO_2 averages exceeded 20 ppm only at sites #105, 108, 115 and 122 between November 1974 and April 1975. For many days during the thirty month test period the SO_2 , H_2S and total sulfur levels did not exceed the detection limits of the instruments. The ozone concentration showed similar seasonal changes as the temperature. Sites which were close to the center of St. Louis had lower ozone but higher NO_x and total hydrocarbon levels. The sulfate concentration was about twice as high in the summer months as in the winter months.

A first attempt has been made to provide a statistical correlation between corrosion and atmospheric data using a multiple regression model. Some of the apparent inconsistencies which seem to occur in the estimated effects of pollutants on corrosion behavior are believed to be due to multicollinearity.

Corrosion (CCN) and Pollutant Code Numbers (PCN) have been assigned to each test site based on the average corrosion values and pollutant levels. No obvious correlations between corrosion behavior and atmospheric conditions can be obtained by comparison of these numbers.

A number of additional experiments have been carried out during this program which were not required under Task Orders No. 26 or 112. The results of tests, which were provided by the persons responsible for the individual experiments, are described in the Appendix. Al samples have been exposed by ALCOA in order to determine the nature of the corrosion products formed during exposure at the different test sites and to correlate these findings

with the stress corrosion cracking behavior of the Al tensile samples. Washington University exposed bronze samples at five test sites to provide fundamental data for their outdoor bronze monument conservation program. CLIMAT samples obtained from ARMCO Steel Corporation have been exposed at all sites. Results for one year starting in April 1976 have suggested that the corrosivity of these test sites is negligible. Atmospheric corrosion monitors exposed by Rockwell Science Center personnel have been used to provide continuous records of time-of-wetness and corrosivity at up to four test sites.

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1.0 INTRODUCTION

In April 1974, the Environmental Protection Agency issued Task Order No. 26 under the Regional Air Pollution Study (RAPS) in St. Louis to begin a four-year exposure study which would assess the damaging effects of sulfur pollutants on various materials. This field study complemented laboratory work carried out by the Materials Section of EPA using controlled environment chamber studies for evaluating the interaction of pollutants such as sulfur dioxide, ozone, oxides of nitrogen, and various materials.

Upon receiving Task Order No. 26, Science Center personnel developed a study plan, acquired material and equipment, erected exposure racks at selected test sites and commenced the exposure program during October 1974. Task Order No. 112 was initiated in May 1976 to continue the exposure study. This report covers the results obtained during the thirty-month exposure period between October 1974 and April 1977 when the project was terminated. Included are corrosion damage data and a summary of atmospheric data collected during this period. An attempt to correlate corrosion and atmospheric data has been made.

2.0 OUTLINE OF TEST PLAN

2.1 MATERIALS, EXPOSURE CONDITIONS AND ASSESSMENT OF CORROSION DAMAGE

The materials for this study were selected by the Materials Section of EPA. Table 1 lists the materials studied, the preparation of the samples, the exposure conditions and the methods of assessment of corrosion damage. A more detailed description is given in Ref. 1. The exposure racks for exposure at 30° from horizontal facing south constructed per ASTM specifications were purchased from the Olin Corporation, New Haven, Connecticut. Exposure racks for vertical exposure of house paint on stainless steel were designed and fabricated at the Science Center using redwood panels to hold the samples in an aluminum frame. The samples were held in place using porcelain insulators. The holders for the nylon samples were located on both sides of the top of the rack. The Al tension samples, which were purchased from Alcoa Technical Center, Alcoa Center, Pennsylvania, were delivered stressed to a fixed stress level (Table 1) and mounted in test frames. The arrangement of the test racks on the roofs of the RAMS shelters is shown in Figure 1.

2.2 EXPOSURE SITES

The Regional Air Monitoring System (RAMS) in St. Louis consisted of 25 stations for collection of aerometric data. A description of this completely automated system can be found in Ref. 3. The nine sites shown in Figure 2 on an inner and an outer ring were selected for this study based on criteria related to monitoring of air quality data important for this exposure study including analysis of particulate matter, which is not provided at all RAMS sites, and to a reasonable spread of the test sites in the area covered in the RAMS study.

2.3 EXPOSURE AND REMOVAL SCHEDULE

The basic exposure and removal schedule was provided by the EPA in Task Order No. 26. This schedule was followed with the exception that additional samples of galvanized and weathering steel were exposed at three-month intervals during the first year to allow a study of the effects of seasonal variations on the corrosion behavior of these materials. The total number of samples at a given test site reached a maximum nine months after start of the exposure test and declined until the end of the program in March 1977.

2.4 AIR QUALITY DATA

Air quality data were routinely collected at each RAMS test site. For the exposure study, the parameters listed in Table 2 were considered important. These data were received from the St. Louis branch of the Rockwell International Air Monitoring Center on tapes in the form of one-hour averages with the exception of sulfate, nitrate and particulate matter data, which were prepared from hi-vol data at the Thousand Oaks branch of the Air Monitoring Center.

The hourly averages received from St. Louis were further processed at the Science Center to produce daily and weekly averages, maxima and minima and standard deviations as discussed in the one-year (1) and two-year (2) reports. For this final report only validated quarterly average data received from AMC St. Louis for the various exposure periods were used.

2.5 ADDITIONAL EXPERIMENTS

A number of experiments not included in the Task Order specifications were added to the program at various times. Since samples for the tests were provided and analyses of the results carried out by the persons who were responsible for these experiments, no additional costs were incurred. The Alcoa Technical Center requested permission to expose a number of different aluminum alloys for determination of pH, Cl^- , NO_3^- and SO_4^{2-} content of the corrosion products, and metallographic determination of type and depth of attack. These panels were exposed at the start of the program at all sites. In April 1976 the first set of CLIMAT (Classification of Industrial and Marine Atmospheres) devices was exposed at all sites. Professor D. W.

Zimmerman of Washington University in St. Louis exposed samples of two different bronzes at five sites in April 1975. Finally, atmospheric corrosion monitors (ACM) as described by Mansfeld and Kenkel (4,5) were exposed at different times and different test sites. Results from these additional exposure tests are included in the Appendix.

3.0 CORROSION DATA - RESULTS AND DISCUSSION

The corrosion damage data are listed in the following sections for the different materials exposed under this program. In addition to the weight loss data, the integral corrosion rate V_i , which is defined as:

$$V_i(t) = \frac{\Delta m}{t} = \tan \alpha, \quad (1)$$

has been calculated from the weight loss Δm per sample area A as a function of time t . The true, differential corrosion rate V_d is defined as:

$$V_d(t) = \frac{d\Delta m}{dt} = \tan \beta. \quad (2)$$

Figure 3 serves to explain the definition of both corrosion rates. If a sufficient number of data points are collected, V_d can be obtained as the tangent of the Δm - time t curve as shown in Figure 3. In the present program, data points are available only for 3, 6, 12, 24 and 30 month periods which makes an accurate determination of V_d -data difficult. However, it is possible as discussed by Bohnenkamp, et al. (6), to calculate V_d -values from experimental V_i -values provided that V_i can be expressed as:

$$V_i(t) = kt^{-n} \quad (3)$$

where $0 \leq n \leq 1$. A value of $n = 0.5$ indicates that the corrosion rate is determined by diffusion of species involved in the corrosion process such as oxygen through the corrosion product layer.

From Eqs. (1) and (3) one finds for the weight loss per unit area Δm :

$$\Delta m = V_i(t) \cdot t = kt^{1-n} \quad (4)$$

and by differentiation according to Eq. (2):

$$V_d(t) = \frac{d\Delta m}{dt} = k(1-n)t^{-n} \quad (5)$$

$$= (1-n)V_i(t) \quad (6)$$

According to Eq. (6) the two functions $V_i(t)$ and $V_d(t)$ differ only by the factor $1-n$. The experimental weight loss data have been converted to $V_i(t)$ -data and in some cases the factors n and k have been determined. The atmospheric corrosion behavior of a material is characterized by the two empirically determined factors k and n .

3.1 GALVANIZED STEEL

The weight loss data for the four sets of galvanized steel are recorded in Table 3. For the first and second sets of galvanized steel and weathering steel, 3, 6, 12 and 24 month data have been obtained. For the first set only, 30 month data are also available. For the third and fourth sets, 3, 6 and 12 month data have been obtained. For the third set, 15 month data are shown in Table 3 which are the result of removal of the wrong samples in July 1976. For the fourth set, only 21 months had expired when exposure ended in April 1977.

Some of the data of Table 3 are plotted in Figures 4 and 5. The results for the first set in Figure 4 show that after 30 months the weight loss was the highest at site #108 and the lowest at site #120. Assuming linear behavior between 6 and 30 months (constant corrosion rate) the differential corrosion rate is seen to fall between 1.04 and 0.84 $\mu\text{m/yr}$ (Figure 4). Weight loss can be converted to change of coating thickness based on the density of zinc (7.13 g/cm^3) using:

$$\frac{\Delta m}{t} \frac{4.52}{\text{g}} = \Delta d \text{ } (\mu\text{m/yr}),$$

where Δm is the weight loss per panel in grams and t the time in years. The integral corrosion rates in Table 4 can be converted into changes of coating thickness as:

$$100 \mu\text{g/cm}^2 \text{ month} \approx 1.68 \mu\text{m/yr}$$

The weight loss data in Figure 5 for the four sets exposed at site #103 show the effect of the time of the year at which galvanized steel is first exposed on the corrosion rate during further exposure. The highest weight loss is observed for the samples which had been first exposed in October 1974, while samples exposed in April and July 1975 had the lowest weight loss.

The data in Figure 5 also show that there is a slight decrease of corrosion rates with time for the first two sets.

The curves extending to 36 months in Figure 5 have been constructed using Eq. (4) and the appropriate n and k values which have been obtained in $\log \Delta m$ - $\log$ time plots as shown in Figure 6 for site #103. The n and k values for the four sets at all sites are listed in Table 5, which shows the interesting results that n is the highest for the first two sets and approaches zero for the third and fourth set. A value $n = 0$ indicates corrosion without film formation at a constant corrosion rate. The constant k , which is equal to the integral corrosion rate expressed in units of weight loss per month, is also larger for the first and second set. The combined influence of n and k leads to initially higher corrosion rates with film formation for the first two sets with corrosion rates approaching those of the third and fourth set at longer times. The total weight loss Δm and true, differential corrosion rates for 36 months can be calculated by extrapolation using Eq. (4) and Eq. (5) for the data in Table 5. For sites 103 and 112 one obtains:

	Site 103		Site 112	
	$\Delta m(\text{mg}/\text{cm}^2)$	$V_d(\mu\text{m}/\text{yr})$	$\Delta m(\text{mg}/\text{cm}^2)$	$V_d(\mu\text{m}/\text{yr})$
1st Set	1.91	0.70	1.88	0.79
2nd Set	1.89	0.72	1.59	0.64
3rd Set	1.49	0.60	1.26	0.57
4th Set	1.49	0.62	1.44	0.68

The integral corrosion rate data (V_i) in Table 4 have to be multiplied by the factor $1-n$ to obtain the true, differential corrosion rates V_d . For the data in Figure 4 these values fall between 0.79 and 0.64 $\mu\text{m}/\text{yr}$. Corrosion rates obtained in St. Louis, Missouri in 1967 and 1968 in the Interstate Surveillance Project (7) were between 2.4 and 6.0 $\mu\text{m}/\text{yr}$. The k -values in Table 5 correspond to the weight loss after one month and are an indication of the corrosivity of a test site. For the first exposure at site #103 in October 1974, $k = 0.135 \text{ mg}/\text{cm}^2$ (2.27 $\mu\text{m}/\text{yr}$), while $k = 0.071 \text{ mg}/\text{cm}^2$ (1.19 $\mu\text{m}/\text{yr}$) for first exposure in July 1975.

Integral corrosion rates V_i listed in Table 4 are plotted in Figure 7 for the four sets of galvanized steel. As observed for site #103 in Figures

5 and 6, V_d -values decrease with time at all test sites. This effect is especially pronounced for the first and second set. Corrosion rates are in general the highest for the first set (first exposure in October 1974) and the lowest for the third set (first exposure in April 1975). The highest V_d -values are found at site #122 after 3 months for the first set (1.51 $\mu\text{m}/\text{yr}$) followed by site #105 (1.24 $\mu\text{m}/\text{yr}$) and site #103 (1.20 $\mu\text{m}/\text{yr}$) after 3 months for the second set. The lowest V_d -values were observed at site #112 after 6 months (0.51 $\mu\text{m}/\text{yr}$) for the third set. This range of corrosion rates assigns a degree of corrosivity of 3 (0.1 to 1.0 $\mu\text{m}/\text{yr}$) on a scale of 5 as defined by Barton (8) to all test sites.

3.2 WEATHERING STEEL

The weight loss data for the four sets of weathering steel are listed in Table 6. Figure 8 shows the weight loss data for the first set of all nine test sites as a function of time. After 24 and 30 months the highest weight loss is observed at site #122, while the weight loss is the lowest at site #105. There is a pronounced decrease of corrosion rates with time as shown in Figures 8 and 9 and, as observed for galvanized steel, the weight loss is higher for the first and second sets. The curves in Figure 9 have been constructed using Eq. (4) with the values of n and k listed in Table 7, which have been determined in $\log \Delta m$ - $\log$ time plots as shown in Figure 10 for site #103. While the average value of n is close to 0.5 for the first three sets, indicating a diffusion controlled mechanism, $n \approx 0.6$ to 0.7 for the fourth set at all sites. A larger value of n indicates a stronger decrease of corrosion rates with time (Eq. (5)) and suggests that a more protective film is formed upon exposure in the summer.

Integral corrosion rates V_i are listed in Table 8 and plotted in Figure 11, which shows again the pronounced decrease of corrosion rates with time. The highest corrosion rates were found for the first three months of the fourth set which was first exposed in July 1975. The highest V_i -values occurred at sites #103 and 108 (70.1 $\mu\text{m}/\text{yr}$) followed by site #122 (64.1 $\mu\text{m}/\text{yr}$) after 3 months for the fourth set. The lowest integral corrosion rates were observed at sites #105 (11.0 $\mu\text{m}/\text{yr}$) and #120 (12.2 $\mu\text{m}/\text{yr}$) after 30 months for the first set and site #105 (11.6 $\mu\text{m}/\text{yr}$) after 21 months of the fourth set. The true, differential corrosion rates (Table 9) as calculated according to

Eq. (5) fall between 32.4 $\mu\text{m}/\text{yr}$ for site #115 after 3 months for the second set and 2.3 $\mu\text{m}/\text{yr}$ for site #105 after 30 months for the fourth set. The differential corrosion rates obtained in this way contain a certain error due to the error in the determination of n and k which assumes that all weight loss data for a given site and set fall on a straight line in a $\log \Delta m - \log t$ plot (Figure 10). In fact, as shown in Figure 12, a distinct pattern is observed at all nine sites in the $\log V_i - \log \text{time}$ curves with different slopes for different time periods for the first set. The decrease of corrosion rates is slower in the summer months than in the winter months. For the last 18 months, $n > 0.5$ for all sites.

3.3 HOUSE PAINT

Table 10 lists the weight loss of house paint (latex base and oil base) on stainless steel for exposure periods of up to 30 months to the north and to the south. For both paints and at all sites a higher weight loss is observed for exposure to the south. A plot of weight loss as a function of time (Figure 13) shows discontinuous corrosion behavior with larger slopes for the first 3 months and between 6 and 12 months exposure. This is also shown in Figure 13 for the integral corrosion rate V_i at site #103. Table 11 and Figure 14 show the V_i -data for all exposure conditions. The highest corrosion rates for latex base paint are found at site #122 for exposure to north and south, while the highest values for oil base paints are found at site #122 for exposure to north and at site #105 for exposure to south. The lowest V_i -values for latex base paints are found at site #105 after 6 months exposure to the north and south. For oil base paint the lowest values are found at sites #112 (north) and #106 (south) after 30 months exposure.

Despite the discontinuous corrosion behavior shown in Figures 13 and 14, a determination of the parameter n is possible as shown in Figure 15 for site #103. The value of n varies from $n = 0.13$ for latex base paint exposed to the south to $n = 0.31$ for oil base paint exposed to the north.

3.4 MARBLE

The weight loss data for marble are listed in Table 12, while the time dependence of the weight loss for two sites is shown in Figure 16. The integral corrosion rates V_i are shown in Figure 17 and listed in Table 13.

The highest integral corrosion rates are found after three months at sites #122, 115 and 120, while the lowest rates are observed after 30 months at sites #106, 112 and 120. The decrease of corrosion rates with time indicates formation of a protective film. The data in Figure 16 show this decrease of corrosion rates in the early stages of exposure. Between 12 and 30 months the corrosion rate seems to be constant; for site #122, where the highest weight loss observed in general, it was about $126 \mu\text{g}/\text{cm}^2$ month, while for site #106, where weight loss data are the lowest, it was found to be $107 \mu\text{g}/\text{cm}^2$ month as determined by a straight line through the data points between 12 and 30 months.

The characteristic constants n and k have been obtained for sites #103, 115 and 122 in Figure 18. Site #103 has the lowest values of n and k , while site #122 has the highest values. The constants for site #122 have been used to calculate a weight loss-time curve in Figure 16 according to Eq. (4). The differential and integral corrosion rates can be calculated from the n and k values of Figure 18 and Eqs. (3) and (5). For the three sites evaluated, one obtains for 30 months (V in $\mu\text{g}/\text{cm}^2 \cdot \text{month}$):

	V_i	V_d
#103	172	138
#115	189	134
#122	191	124

It is interesting to note that while the integral values seem to be the lowest for site #103, the true corrosion rate V_d is the highest for site #103 due to the lowest value of n at this site.

3.5 SILVER

One set each of silver was exposed in the first and second year of this exposure test. Samples were first exposed in mid-October of 1974. The silver samples were evaluated by reflectance loss measurements and by electrochemical reduction of the tarnish film in 3.5% NaCl solution as described earlier (1, 2). Figure 19 shows a typical potential-time curve for reduction of the two and sometimes three types of tarnish film. The first plateau corresponds to an oxide film, while the second arrest in the potential decay

curve is due to reduction of the sulfide film at an applied constant cathodic current. Figures 20 and 21 show the correlation between reflectance loss and amount of electricity consumed for reduction of the tarnish film. The film thickness d can be calculated using the formula:

$$d = k_1 \frac{It}{A} = k_2 Q, \quad (7)$$

where k_1 is a constant, for which a value for silver sulfide of $17.6 \text{ \AA sec/cm}^2$ (9) was used. For a constant applied current of 20mA and an area $A = 364.8 \text{ cm}^2$, Eq. (8) can be written as:

$$d = 0.048Q \text{ (\AA)} \quad (8)$$

for Q in mCb.

Most of the points for exposures of nine months or less fall close to the straight lines in Figures 20 and 21. For longer exposure times a deviation from linearity must occur with increasing film thickness since reflectance loss cannot exceed 100% while the thickness of the tarnish film seems to increase continuously. This becomes evident especially in the results for the second year (Figure 21), where RL did not exceed 80 to 90%, while the film thickness varied from 300 to 500A. The slope in the linear region was similar for both sets of samples. The reflectance loss was somewhat higher in the second year of exposure.

As shown in Tables 14 and 15, the highest reflectance loss after twelve months was observed at sites #115, 105 and 108 and the lowest at sites #118 and 112 for the first set. For the second set, the highest RL values were found at sites #108, 115 and 122 and the lowest at sites #106 and 112.

3.6 ALUMINUM TENSION SAMPLES

The number n_s of samples surviving as a function of time is shown in Figure 22 for the nine test sites. Nine samples each of Al 2014 at 25 and 45 kilopounds per square inch (Ksi) and of Al 7079 at 15 and 25 Ksi had originally been exposed. All samples of Al 7079 at 25 Ksi failed in the first 255 days. At the lower stress level of 15 Ksi all samples failed in less than 630 days except at site #120, where two samples remained. Time-to-failure for Al 2014 at 45 Ksi showed much wider variations. At site #103 all

nine samples failed in 66 days, while one sample each remained unbroken at sites #112 and 115. Not many samples of A1 2014 at 25 Ksi failed in 30 months. Only at sites #104 and 108 did all samples fail. At site #106 only one sample cracked. Less than fifty percent of all samples failed at sites #106, 108, 112 and 115 (Table 16).

The shortest time-to-failure for A1 7079 at 25 Ksi was observed at sites #105, 103 and 122, while the longest time-to-failure occurred at sites #112 and 115. Failure occurred in the shortest time for A1 7079 at 15 Ksi at sites #122, 115 and 105, for A1 2024 at 45 Ksi at sites #103, 120 and 105, and for A1 2024 at 15 Ksi sites #105 and 108.

3.7 NYLON

In the first year of this program new nylon samples were exposed every month. However, no conclusive results were obtained, as only eight out of 216 samples were damaged. In most cases the cause for the damage could not be determined. During the second year, nylon samples were exposed for three-month intervals. Some samples showed severe damage which might have been caused by birds. Table 17 lists the number of samples with holes and the number of holes observed for the four sets during the second year. While for the first set only one and for the second set only three samples out of 18 samples had shown holes, a large number of failures occurred for the second and third set, which were exposed in January and April 1976.

4.0 AIR QUALITY DATA - RESULTS AND DISCUSSION

Edited tapes have been received from the Air Monitoring Center in St. Louis with quarterly averages for wind speed, wind direction, temperature, relative humidity, ozone, NO_x , total hydrocarbons, total sulfur, SO_2 and H_2S for the time period between November 10, 1974 and March 31, 1977. The data presented in this report are validated data. The wind direction data have also been analyzed in wind rose format; however, these are not incorporated in this report due to the large volume of data. Simple average values are, therefore, reported. The relative humidity (RH) data do not seem to be correct in all cases, however, they are included for general information.

Particulate matter data beginning with mid-January 1975 are also reported. Values for total suspended particulates had not been available earlier while the data for sulfate and nitrate had been available only for parts of the test period and then not as concentrations ($\mu\text{g}/\text{m}^3$).

Tables 18 and 19 list the quarterly average values for the air quality parameters including particulate matter (Table 19). These data are also plotted in Figures 23 and 24 for site #103 where, in general, rather high corrosion rates are observed; for site #106 where rather low corrosion rates but high pollution levels occur; for site #118 where corrosion rates are intermediate but pollution levels low; and for site #122 where for many materials the highest corrosion rates are measured. Since SO_2 and H_2S are not monitored at site #118, data are plotted for site #115, which shows the highest H_2S values.

The effect of seasonal variations becomes evident from Figures 23 and 24, especially for ozone and NO_x (Figure 23) and total suspended particulates, sulfate and nitrate (Figure 24). In the summer months, when temperatures are high, the ozone levels are high, but the NO_x levels are low. The NO_x levels are higher in the center of the city than in the rural areas.

Total suspended particulates showed maxima in the April/July quarter of 1975 and July/October quarter of 1976 (Figure 24a) which parallel those found for ozone (Figure 23h). Similar results were found for sulfate (Figure 24b), except that the 1975 maxima occur in the April/July quarter for sites #118 and 122, which are rural, and in the July/October quarter at sites #103 and 106 which are within the city. The average nitrate values (Figure 24c) have broad maxima in the October/January 1975 and January/April 1976 quarters.

4.1 SULFUR DIOXIDE

In Table 18 the quarterly averages of the SO_2 concentration are listed. Figure 23f shows the same values for sites #103, 106, 115 and 122. The SO_2 levels remain at low and constant values with the exception of site #115. Upham (10) has reported mean SO_2 concentrations up to 130 ppb at 10 metropolitan sites in St. Louis for the time period between December 1964 and February 1965.

While Table 18 and Figure 23f show the average values for SO_2 for the different three month periods between November 10, 1974, when the first air quality data were available, and April 14, 1977, when the experiment was terminated; Table 20 and Figure 25b show the average values for SO_2 concentration for different exposure periods as calculated from the data of Table 18 for the individual quarters. For the exposure period starting November 1974, the average SO_2 concentration decreases during the 30 month period. The highest values are initially observed at sites #115, 108 and 122. For the total 30 month period, the highest average values occurred at sites #115, 106 and 108. Site #120 had the lowest SO_2 levels for all exposure periods. There is a decrease in the average SO_2 concentration from 1974 to 1975. Samples first exposed at site #103 in November 1974 were exposed to an average concentration of 32.6 ppb during the first three months, while for samples first exposed at the same site in January, April and July 1975, respectively, the average concentrations were 11.4, 8.5 and 9.5 ppb. These differences in initial SO_2 concentrations might in part explain the pronounced effect on subsequent corrosion behavior of the time of the year when samples were first exposed as observed especially for galvanized steel.

4.2 HYDROGEN SULFIDE

As observed in the previous reports (1, 2) the H_2S levels are rather low except at site #115 which is close to refineries. For the time period between July 9 and October 14, 1975 an average of 120 ppb and for the time period between October 15, 1975 and January 14, 1976 an average of 126 ppb was observed (Table 18, Figure 23g) at site #115. From the quarterly averages in Table 18 it can be seen that the average H_2S values exceed the detection limit of the instrument, which was 5 ppb, only for some periods of the entire exposure time.

The average values for the different exposure periods as calculated from the quarterly values in Table 18 are shown in Table 20 and Figure 25c. The most significant trend in Figure 25c might be the decrease of the H_2S concentration with increasing exposure time at sites #103, 105 and 108, the increase at site #120 for all four sets, and the extremely high values for site #115 starting in July 1975.

4.3 TOTAL SULFUR

The average values for total sulfur are listed in Table 18. Figure 23e shows the data for four different sites. As discussed for SO_2 , the total sulfur values were the highest between November 1974 and April 1975. The maxima reported for SO_2 concentrations in New York in the winter months, when more oil and coal are burnt, were not so pronounced in St. Louis during the winter of 1975/1976, but can be seen for the winter of 1976/1977. It might be significant for an explanation of the observed corrosion behavior and the time-of-wetness data that the lowest average temperature at the four sites shown in Figure 23c was between 5 and 6°C in 1975/1976 and between 0 and 2°C in 1976/1977.

Table 20 and Figure 25a list the average values for exposure periods starting at four different times of the year. The decrease in the average sulfur levels from the winter to the summer can be seen again. For the first two exposure periods the averages decrease with increasing exposure time. The data for site #115 reflect the very high H_2S concentrations. For site #122, where the highest total sulfur levels were initially observed, rather low values are found for the exposure period starting in July 1975. Sites

#112, 118 and 120 have the lowest sulfur levels for all periods.

4.4 OZONE

The changes with time of the mean ozone concentration shown in Figure 23h are similar to those for temperature (Figure 23c) with maximum values between April and October. The ozone levels are higher at the two rural sites #118 and 122 than at the other sites (Figure 23c and Table 18). This particular time dependence explains the changes with time of the average ozone levels calculated in Table 20 and Figure 25d for the various time periods starting at different times of the year. For exposure starting in November 1974 the average ozone levels increase with time for 24 months and then decrease again for the last six months. On the other hand, for exposure starting in April 1975, the average values decrease during the first year and are higher again for the total 24 month period. For exposure starting in July 1975 a minimum occurs for the six month period which covers part of the summer, fall and winter.

It will be noted that the average ozone and SO_2 concentrations change in opposite directions with exposure period due to the different time dependence during a given year.

4.5 OXIDES OF NITROGEN

The changes of the quarterly averages with time plotted in Figure 23i show higher values in the winter months than in the summer. Contrary to the ozone levels, the NO_x levels are the lowest at the sites which are farther away from the city (#115, 118 and 122). For the exposure period starting in November 1974, NO_x levels exceed 40 ppb at sites #105, 106 and 112 for all time periods (Figure 25e and Table 20), but stay below 20 ppb at sites #115, 118 and 122. Similar results are observed for the three other sets of measurements.

The observed dependence of the NO_x concentration on the time of the year leads to the time dependence of the average values for exposure starting at different times of the year (Figure 25e, Table 20). For the test started in November 1974 average values decrease with exposure time between six and twelve months since the NO_x levels are lower in the summer. For the same reason average values increase for tests started in April and July 1975.

4.6 TOTAL HYDROCARBON

The quarterly averages for hydrocarbon (Table 18, Figure 23j) did not show significant changes with time or location. As shown in Figure 25f and Table 20, the 2 ppm level is exceeded at site #105 for exposure up to 30 months and at sites #106 and 108 for 24 and 30 month periods for exposure starting in November 1974. Similar results are found for exposure tests starting at later dates. Sites #115, 118 and 122 have the lowest THC levels.

4.7 WIND SPEED, WIND DIRECTION, TEMPERATURE AND RELATIVE HUMIDITY

The quarterly averages for wind speed, wind direction and temperature are listed in Table 18 and Figure 23a-c for four test sites. The wind speed is higher in the time between October and April than in the other months. The changes in wind direction with time of the year do not seem to be too clear from the scalar average values reported here. More information is available from the wind rose data compiled by the Air Monitoring Center in St. Louis. The winter of 1975/1976 was warmer as the winters of 1974/1975 and 1976/1977.

The data reported earlier (1, 2) for relative humidity, which are based on dew point measurements, have been revised to eliminate obviously erroneous data. Table 18 and Figure 23d show these RH-data, which indicate that the quarterly averages for sites #106, 118 and 122 fall into a narrow band between 60 and 75%. The values for site #103 seem to be lower and fall between 40 and 70%. For a detailed evaluation of atmospheric corrosion it seems necessary to obtain daily or even hourly RH averages to explain variations in corrosion rates. The time-of-wetness data reported below become important in this respect. Since the RH data still do not seem to be very reliable, RH values from the International Airport in St. Louis, which have been provided by F. H. Haynie of the EPA, are also included in Figure 23d. These data show that the highest quarterly RH average was about 81%, while the lowest value was about 66%.

4.8 PARTICULATE MATTER

The quarterly averages for total suspended particulate (TSP), sulfate and nitrate concentration are shown in Table 19 and Figures 24a-c. The

average values for the different time periods calculated considering the number of sample days are listed in Table 21 and plotted in Figures 26a-c.

The quarterly averages for TSP and sulfate show pronounced changes with the time of the year which are quite similar to those observed for ozone (Figure 23h). Maxima are observed for the period from April to July 1975 and July to October 1976 for TSP and sulfate with the exception that the maxima occurred between July and October 1975 at sites #103 and 106. It is interesting to note that the total sulfur and SO_2 average showed a minimum for the July/October 1975 quarter. For nitrate (Figure 24c), maxima occurred in the winter months of 1975/1976 and apparently also 1976/1977. The highest values for nitrates were observed for the January/April 1975 quarter at sites #103, 106 and 122.

The averages calculated as a function of exposure time in Table 21 and Figure 26 show that in general particulate matter concentrations are lower at sites #115, 118 and 122. The changes of the particulate matter concentrations with the time of the year (Figure 24, Table 19) give rise to the changes of the average concentration with time of exposure and start of exposure (Table 21). For start in November 1974, no three month averages are available. For TSP and sulfate, the lowest average values occurred for the six month exposure period followed by a maximum for twelve months. For the remaining periods, average concentrations for TSP, sulfate and nitrate decreased. For TSP and sulfate, concentrations decreased in general with increasing exposure time for all four starting dates, while for nitrates, where the changes of the average concentrations were smaller, increases or decreases were found depending on exposure sites and time of initial exposure.

5.0 CORRELATION BETWEEN CORROSION AND ATMOSPHERIC DATA

5.1 INTRODUCTION

The results described below are a first attempt to relate the integral corrosion rate to various atmospheric pollutants, duration of exposure and other atmospheric factors. Various materials exposed at the different sites are considered. It was postulated that the logarithm of the integral corrosion rate V_i (Eq. (3)) for each material considered in this report is linearly proportional to the pollutants and other corrosive atmospheric factors and linear in the logarithm of time of exposure. The model is thus a multiple regression model with the dependent variable being log corrosion rate and the so-called independent variables being the atmospheric parameters and log time. The coefficients in the model represent the marginal effects of the pollutants, exposure time and other atmospheric factors. The analysis was done for all materials except silver and Al alloys at all test sites and is presented in tabular form. Some of the apparent inconsistencies in the estimated effect for different materials or different sets of materials are clearly due to the interdependence of the so-called independent variables in the multiple regression model. This situation is known as the problem of multi-collinearity.

In a subsequent analysis, one could account for near multi-collinearity of the regression model by incorporating into the model the obvious as well as the postulated interrelationships between the explanatory variables in the multiple regression model. A factor analysis of the independent variables space may be productive in identifying the near multi-collinearities. After identification they could be removed from the analysis by appropriately defining a reduced set of new variables which are not as highly correlated.

As the analysis now stands, there is a high degree of uncertainty in the estimated regression coefficients. This makes it very difficult to determine if the linearity assumptions for the explaining variables are valid. Time and funding constraints did not permit an extensive residual analysis

to identify distributional characteristics or multi-dimensional outliers. Clearly, this is a task that yet needs to be done.

5.2 THE STATISTICAL MODEL

The statistical model considered for analysis is:

$$V_i(t) = kt^{-n} \cdot 10^{\sum_{j=1}^m \beta_j X_j(t)} + \epsilon_i \quad (9)$$

where $V_i(t)$: integral corrosion rate

k : time independent effect on corrosion rate

n : effect of exposure time on corrosion rate

$X_j(t)$: level of the j^{th} pollutant to which the material is exposed

β_j : coefficient of the j^{th} pollutant on integral corrosion rate

ϵ_i : random error

In view of the relation

$$V_i(t) = \frac{\Delta m}{t} \quad (1)$$

Eq. (9) can equivalently be written in terms of weight loss Δm_t :

$$\Delta m(t) = kt^{1-n} \cdot 10^{\sum_{j=1}^m \beta_j X_j(t)} + \epsilon_i \quad (10)$$

The log-linear form of the model in Eq. (9) is considered to fit for the experimental data and is given by:

$$\log V_i(t) = \log k - n \log t + \sum_{j=1}^m \beta_j X_j(t) + \eta_i \quad (11)$$

where it is assumed that the random errors η_i in Eq. (11) are independently, identically distributed Gaussian Variates.

The pollutants considered in this analysis are TS, SO_2 , H_2S , O_3 , NO_x , TSP, SO_4 and NO_3 . Analysis has been considered for all materials taking the

data for all nine sites for a given test period except the stressed Al samples and silver for which weight loss data have not been obtained. Different statistical models have to be prepared for these materials.

5.3 RESULTS

The empirical model proposed above is fitted to the experimental data and the effects of exposure time and the pollutant levels are determined and tested for statistical significance which is indicated by:

F-ratio: Snedecor's F-statistic associated with the hypothesis that all coefficients in the regression are zero.

R^2 : proportion of the total variance of the dependent variable explained by the regression.

S: standard error of residuals.

The forward stepwise regression program, BMDP2R, in the Biomedical Computer Programs package (11) was used to analyze the data. At each step in the analysis, that explaining variable which reduces the residual variance the most is included. Due to the problem of collinearity, it is important to include all variables in the analysis to test the significance of any one variable. This is because the explaining power of a particular variable may be totally due to the fact that it is correlated with another variable actually causing the observed corrosion behavior. If the test matrix is not too unbalanced, the collinearity will be properly accounted for in a multiple regression analysis and the test of the hypothesis that a particular variable is significant will be more valid. In order that all variables be included in the analysis, the forcing option of BMDP2R was invoked. The explaining variables were somewhat arbitrarily divided into three subsets:

A = {NO₃, SO₄, TSP, TS, log t}

B = {SO₂, H₂S}

C = {O₃, NO_x}

The order of entry of the variables specified in Table 22 is dictated by the largest reduction in residual variance criterion except that all

variables in set A are included before any variables in sets B or C are considered and then all variables in B are included before the variables in set C are considered. For this reason, for example, O_3 and NO_x are always the last two variables entering the regression. O_3 enters before NO_x because it causes a larger reduction in the residual variance than NO_x .

Table 23 shows the results of the significance tests concerning the effects of each of the explaining variables. In particular, the hypothesis that the true regression coefficient of each of the variables $\log t$, TS, SO_2 , H_2S , O_3 , NO_x , TSP, SO_4 , NO_3 is zero is being tested in the multifactor environment including all variables simultaneously. It can be seen from Table 23, that in every case except galvanized steel/set 1 and Latex the time effect is real (greater than 95% confidence). In the case of Latex, North, corrosion is being explained primarily by the TS, SO_2 , and H_2S variables. For Latex, South, corrosion is correlated with TS, SO_2 , O_3 , NO_x , TSP, and SO_4 . For galvanized steel/set 1, the corrosion rate is primarily correlated with TSP and NO_x .

5.3.1 Galvanized Steel

For galvanized steel, time of exposure and NO_3 had the most important effects, NO_3 being an accelerating factor (Table 22a). NO_x seems to have the least effect for the first set, which might be due to collinearity between NO_x and NO_3 . For the second and fourth set O_3 was considered last. TS and TSP were considered third and fourth in the first set followed by the other sulfur containing pollutants. The effect of sulfur pollutants seems to be spread over the compounds which make it impossible at this stage of the analysis to determine the role played by the different sulfur pollutants.

5.3.1.1 First Set

α , Explaining variable: time of exposure t

$$\log V(t) = 1.977 - 0.144 \log t; F_{1,22} = 16.885,$$

$$R^2 = 0.4342, S = 0.0471$$

β, Explaining variables: t, TS, TSP, NO₃

$$\log V(t) = 1.568 - 0.048 \log t + 0.003 \text{ TS} \\ + 0.001 \text{ TSP} + 0.024 \text{ NO}_3$$

$$F_{4,19} = 13.416, R^2 = 0.7385, S = 0.0345$$

γ, Explaining variables: t, TS, TSP, NO₃, H₂S, SO₄

$$\log V(t) = 1.557 - 0.045 \log t + 0.003 \text{ TS} \\ + 0.004 \text{ H}_2\text{S} + 0.001 \text{ TSP} - 0.002 \text{ SO}_4 + 0.028 \text{ NO}_3$$

$$F_{6,17} = 9.269, R^2 = 0.7659, S = 0.0345$$

5.3.1.2 Second Set

α, Explaining variable: t

$$\log V(t) = 1.954 - 0.178 \log t$$

$$F_{1,13} = 28.198, R^2 = 0.5508, S = 0.0528$$

β, Explaining variables: t, TS, SO₂, H₂S, NO_x, TSP, SO₄, NO₃, O₃

$$\log V(t) = 1.863 - 0.102 \log t + 0.004 \text{ TS}$$

$$- 0.005 \text{ SO}_2 + 0.005 \text{ H}_2\text{S} - 0.005 \text{ O}_3$$

$$- 0.002 \text{ NO}_x + 0.003 \text{ TSP} - 0.008 \text{ SO}_4$$

$$+ 0.018 \text{ NO}_3$$

$$F_{9,15} = 9.969, R^2 = 0.8568, S = 0.0369$$

5.3.1.3 Third Set

Due to an error in the data input for the regression analysis, which could not be corrected, a regression analysis is not available for the third set of galvanized and weathering steel.

5.3.1.4 Fourth Set

α, Explaining variable: t

$$\log V(t) = 1.766 - 0.080 \log t$$

$$F_{1,26} = 4.174, R^2 = 0.1383, S = 0.0695$$

β, Explaining variables: t, TS, SO₂, H₂S, NO_x, TSP, SO₄, NO₃

$$\log V(t) = 1.911 - 0.184 \log t - 0.005 \text{ TS} +$$

$$0.013 \text{ SO}_2 - 0.011 \text{ H}_2\text{S} - 0.004 \text{ NO}_x$$

$$+ 0.002 \text{ TSP} - 0.022 \text{ SO}_4 + 0.070 \text{ NO}_3$$

$$F_{8,19} = 7.959, R^2 = 0.7702, S = 0.0420$$

5.3.2 Weathering Steel

For the first set of weathering steel (Table 22b), time of exposure, TS, SO_4 , and TSP were the most important pollutants, while O_3 and NO_x , which seem to decelerate corrosion rates, were considered last. While the coefficient for O_3 is positive for the first set, it is negative for the second and fourth set.

5.3.2.1 First Set

α , Explaining variable: t

$$\log V(t) = 0.822 - 0.545 \log t$$

$$F_{1,22} = 75.879, R^2 = 0.7752, S = 0.0839$$

β , Explaining variables: $t, \text{TS}, \text{SO}_4, \text{TSP}, \text{NO}_3, \text{H}_2\text{S}, \text{SO}_2, \text{NO}_x$

$$\log V(t) = 0.702 - 0.588 \log t - 0.004 \text{TS}$$

$$+ 0.006 \text{SO}_2 + 0.011 \text{H}_2\text{S} - 0.010 \text{NO}_x$$

$$+ 0.006 \text{TSP} - 0.005 \text{SO}_4 - 0.001 \text{NO}_3$$

$$F_{8,15} = 85.555, R^2 = 0.9786, S = 0.0314$$

5.3.2.2 Second Set

α , Explaining variables: $t, \text{TS}, \text{SO}_2, \text{H}_2\text{S}, \text{NO}_x, \text{TSP}, \text{SO}_4, \text{NO}_3, \text{O}_3$

$$\log V(t) = 0.832 - 0.495 \log t - 0.004 \text{TS}$$

$$+ 0.006 \text{SO}_2 + 0.008 \text{H}_2\text{S} - 0.005 \text{O}_3$$

$$- 0.007 \text{NO}_x + 0.003 \text{TSP} + 0.009 \text{SO}_4$$

$$- 0.027 \text{NO}_3$$

$$F_{9,15} = 27.775, R^2 = 0.9434, S = 0.0550.$$

5.3.2.3 Third Set

Statistical analysis not available.

5.3.2.4 Fourth Set

α , Explaining variable: t

$$\log V(t) = 0.913 - 0.646 \log t$$

$$F_{1,26} = 327.688, R^2 = 0.9265, S = 0.0635$$

β, Explaining variables: t, TS, SO₄, SO₂, H₂S, NO_x, TSP, NO₃

$$\log V(t) = 0.719 - 0.576 \log t - 0.009 TS$$

$$+ 0.016 SO_2 - 0.001 H_2S - 0.005 NO_x$$

$$+ 0.001 TSP + 0.013 SO_4 - 0.001 NO_3$$

$$F_{8,19} = 68.735, R^2 = 0.9666, S = 0.0501$$

5.3.3 House Paint, Latex Facing North

For the latex base house paint (Table 22c), time of exposure was only the fifth (exposure to north) or fourth (exposure to south) important parameter. In both cases NO₃ with a large negative coefficient was chosen first, followed by TSP and SO₄. O₃ which was found to accelerate corrosion, and NO_x were considered last.

α, Explaining variable: NO₃

$$\log V(t) = 1.678 - 0.040 NO_3$$

$$F_{1,22} = 9.988, R^2 = 0.3122, S = 0.0671$$

β, Explaining variables: NO₃, TSP, SO₄, TS, t, SO₂, H₂S, O₃

$$\log V(t) = 1.279 - 0.124 \log t - 0.010 TS + 0.012 SO_2$$

$$+ 0.008 H_2S + 0.014 O_3 - 0.001 TSP$$

$$+ 0.008 SO_4 - 0.005 NO_3$$

$$F_{8,15} = 10.215, R^2 = 0.8449, S = 0.0386$$

5.3.4 House Paint, Latex Facing South

α, Explaining Variable: NO₃

$$\log V(t) = 1.800 - 0.047 NO_3$$

$$F_{1,22} = 9.939, R^2 = 0.3112, S = 0.0783$$

β, Explaining Variables: NO₃, SO₄, TSP, t, TS, H₂S, SO₂, O₃

$$\log V(t) = 0.989 - 0.067 \log t - 0.009 TS$$

$$+ 0.012 SO_2 + 0.002 H_2S + 0.019 O_3$$

$$+ 0.001 TSP + 0.008 SO_4 + 0.004 NO_3$$

$$F_{8,15} = 36.824, R^2 = 0.9515, S = 0.0252$$

5.3.5 House Paint, Oil Facing North

For the oil base paint, time of exposure and SO₄ were most important while NO_x was considered last (Table 22c). This result points out a different behavior of the two types of paints since time of exposure was much less important for latex base paint.

α, Explaining variables: t, SO₄

$$\log V(t) = 1.234 - 0.163 \log t + 0.026 \text{ SO}_4$$

$$F_{2,21} = 8.415, R^2 = 0.4449, S = 0.0744$$

β, Explaining variable: t, SO₄, TS, SO₂, H₂S, O₃, TSP, NO₃

$$\log V(t) = 1.274 - 0.502 \log t + 0.002 \text{ TS}$$

$$- 0.002 \text{ SO}_2 + 0.015 \text{ O}_3 + 0.004 \text{ TSP} + 0.001 \text{ H}_2\text{S}$$

$$+ 0.018 \text{ SO}_4 - 0.033 \text{ NO}_3$$

$$F_{8,15} = 10.815, R^2 = 0.8522, S = 0.0454$$

5.3.6 House Paint, Oil Facing South

α, Explaining variables: t, SO₄

$$\log V(t) = 1.263 - 0.098 \log t + 0.021 \text{ SO}_4$$

$$F_{2,21} = 5.346, R^2 = 0.3374, S = 0.0699$$

β, Explaining variables: t, SO₄, TS, SO₂, H₂S, O₃, TSP, NO₃

$$\log V(t) = 1.415 - 0.451 \log t + 0.002 \text{ TS}$$

$$- 0.003 \text{ SO}_2 + 0.003 \text{ H}_2\text{S} + 0.012 \text{ O}_3$$

$$+ 0.004 \text{ TSP} + 0.011 \text{ SO}_4 - 0.044 \text{ NO}_3$$

$$F_{8,15} = 9.783, R^2 = 0.8392, S = 0.0408$$

5.3.7 Marble

Time of exposure, NO₃ and TSP explain about 87% of the experimental results. The effect of the sulfur pollutants is obscured since it is divided in the present analysis among the various compounds. Ozone seems to accelerate corrosion (Table 22d).

α, Explaining variable: t

$$\log V(t) = 2.709 - 0.306 \log t$$

$$F_{1,22} = 75.434, R^2 = 0.7742, S = 0.0473$$

β, Explaining variables: t, TS, SO₂, H₂S, O₃, TSP, SO₄, NO₃

$$\log V(t) = 2.807 - 0.507 \log t - 0.005 \text{ TS}$$

$$+ 0.006 \text{ SO}_2 + 0.004 \text{ H}_2\text{S} + 0.010 \text{ O}_3$$

$$+ 0.003 \text{ TSP} - 0.013 \text{ SO}_4 - 0.025 \text{ NO}_3$$

$$F_{8,5} = 23.151, R^2 = 0.09251, S = 0.0330$$

5.4 CORROSION AND POLLUTANT CODE NUMBERS

In the statistical analysis of the effects of pollutants on corrosion rates of the different materials, no direct ranking of test sites according to corrosivity or pollutant concentration was given. Such data could be generated by using the results of a more detailed regression analysis and taking into account the acceleration or inhibition of corrosion caused by the different pollutants.

In order to provide a simple survey of the ranking of the nine test sites according to corrosion rates and pollutant concentrations, Tables 24 and 25 have been prepared in which the test sites are ranked according to the severity of corrosion (Table 24) and amount of pollution (Table 25). The highest corrosion rates and highest pollution concentrations are ranked as 1. For the corrosion data, values for 12, 24 and 30 months were considered. For the second to fourth set of galvanized and weathering steel, the corresponding time periods were used. For the Al alloys, results for 100% failure taking into account the number of unbroken samples were used. For the pollutant data, the average values at the end of the four exposure periods in Tables 20 and 21 were considered. The data in Tables 24 and 25 show how the ranking of the various sites changes with material and start of exposure. For galvanized steel, for example, pronounced changes can occur for the four sets, while for weathering steel the ranking of a site is more or less independent of the start of exposure as pointed out above. As a summary of these tabulations, Corrosion and Pollution Code Numbers have been prepared for all sites and materials. For the Corrosion Code Number (CCN), the sequence of numbers corresponds to the ranking of galvanized steel, weathering steel, house paint, marble, silver and stressed aluminum alloys. The rankings for different sets of materials or the two Al alloys at different stress levels have been combined to give one number for each material. In the Pollution Code Number (PCN), the sequence is SO_2 , TS, H_2S , O_3 , NO_x and THC. The particulate matter data of Table 25 have not been considered in the PCN. In this way two six-digit numbers have been prepared:

<u>Site #</u>	<u>CCN</u>	<u>PCN</u>
103	336652	676644
105	494431	432931
106	868977	227712
108	123223	355553
112	779799	X6X815
115	544518	111373
118	652375	X9X189
120	987856	782466
122	211134	534297

Based on the CCN, sites #108 (CCN = 123223) and #122 (CCN = 211134) are by far the most corrosive sites. For these two sites the two corresponding PCNs are 355553 and 534297, indicating average or low pollutant concentrations. On the other hand, for site #106, CCN = 868977 and PCN = 227712 indicate low corrosivity but high concentrations in SO₂, TS, NO_x, and THC. A comparison of CCNs and PCNs does, therefore, not show any obvious correlations between corrosivity and pollution. It has to be considered, however, when comparing CCNs and PCNs that high concentrations of some pollutants might have an inhibiting effect on corrosion rates. Haynie and Upham (12) have concluded that oxidants such as ozone decrease corrosion rates of steels including weathering steel.

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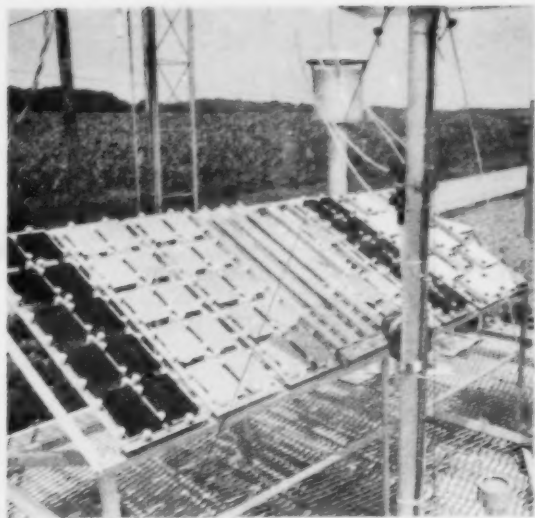


FIGURE 1a



FIGURE 1b

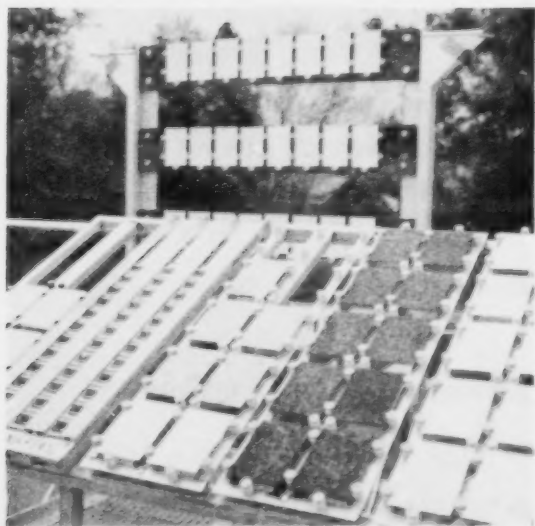


FIGURE 1c



FIGURE 1d

FIGURE 1. ARRANGEMENT OF TEST RACKS ON SHELTER ROOF

■ RAPS CENTRAL
 ● RAPS STATIONS
 ▲ UPPER AIR
 △ SOUNDING STATION

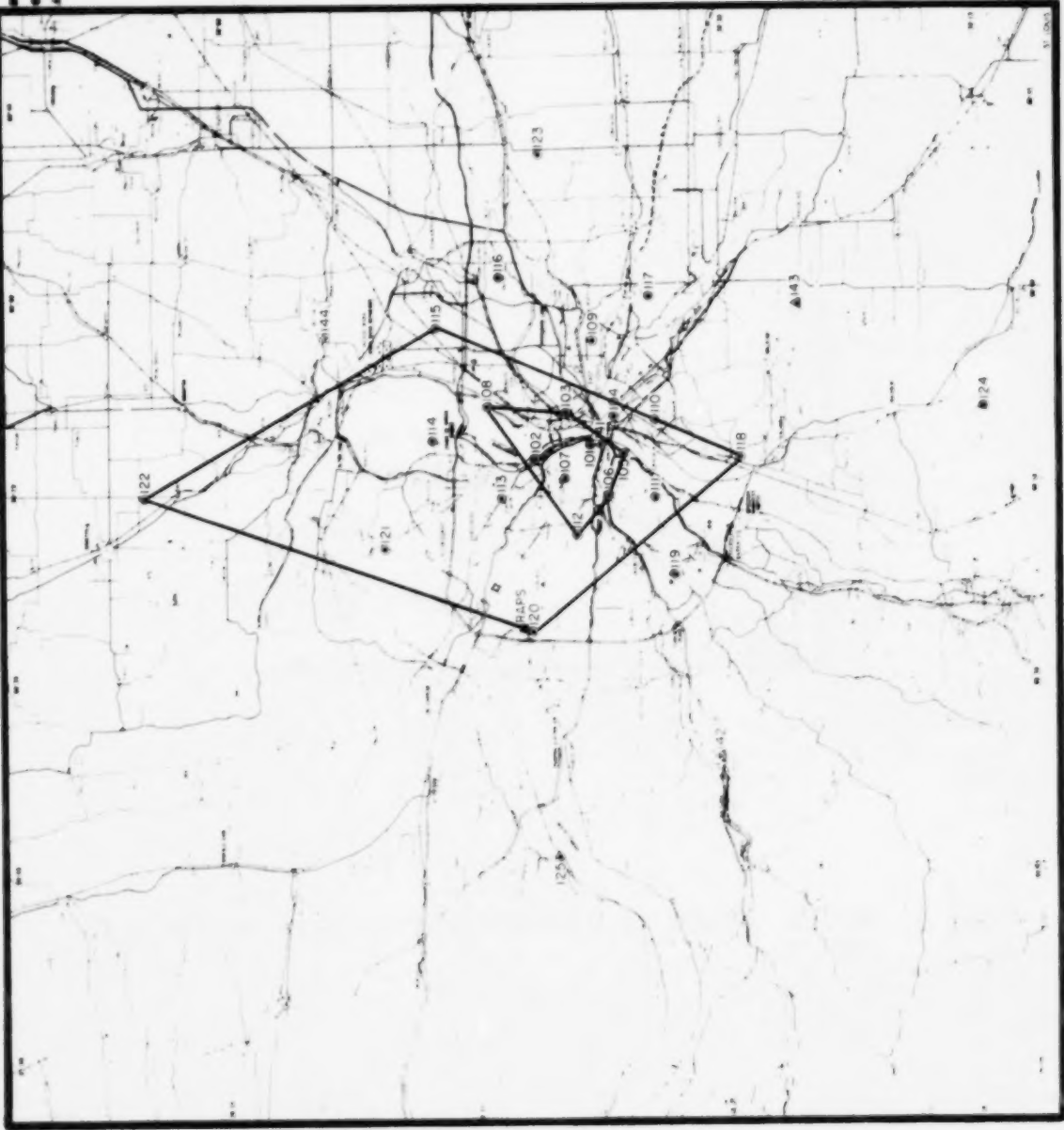


FIGURE 2. LOCATIONS OF TEST SITES

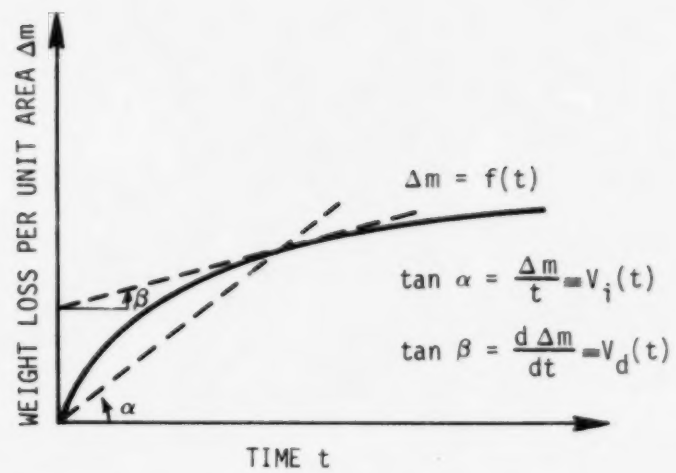


FIGURE 3. DEF. OF INTEGRAL (V_i) AND DIFFERENTIAL (V_d) CORROSION RATES (REF. 6).

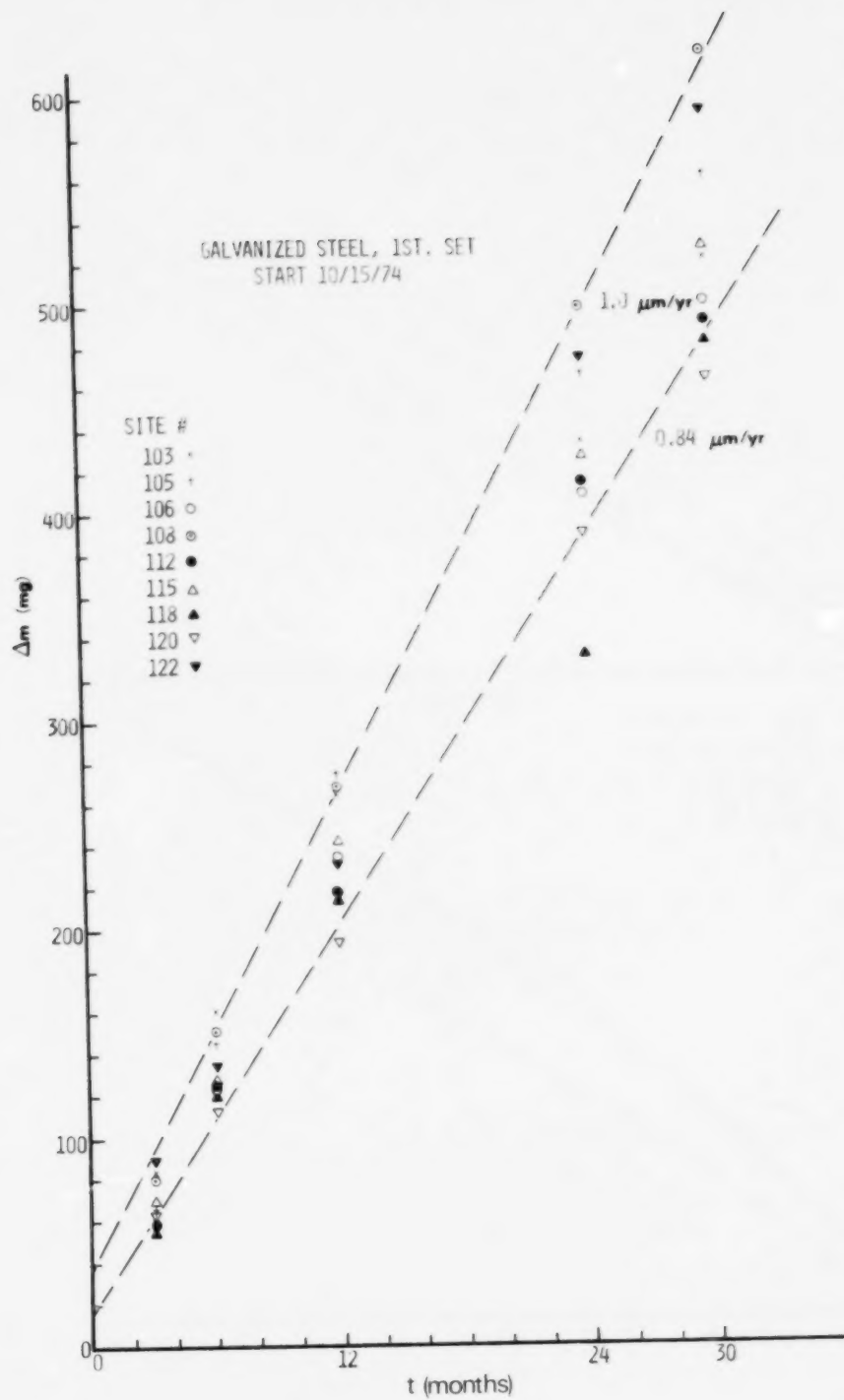


FIGURE 4. WEIGHT LOSS OF GALVANIZED STEEL , FIRST SET, AT THE NINE TEST SITES.

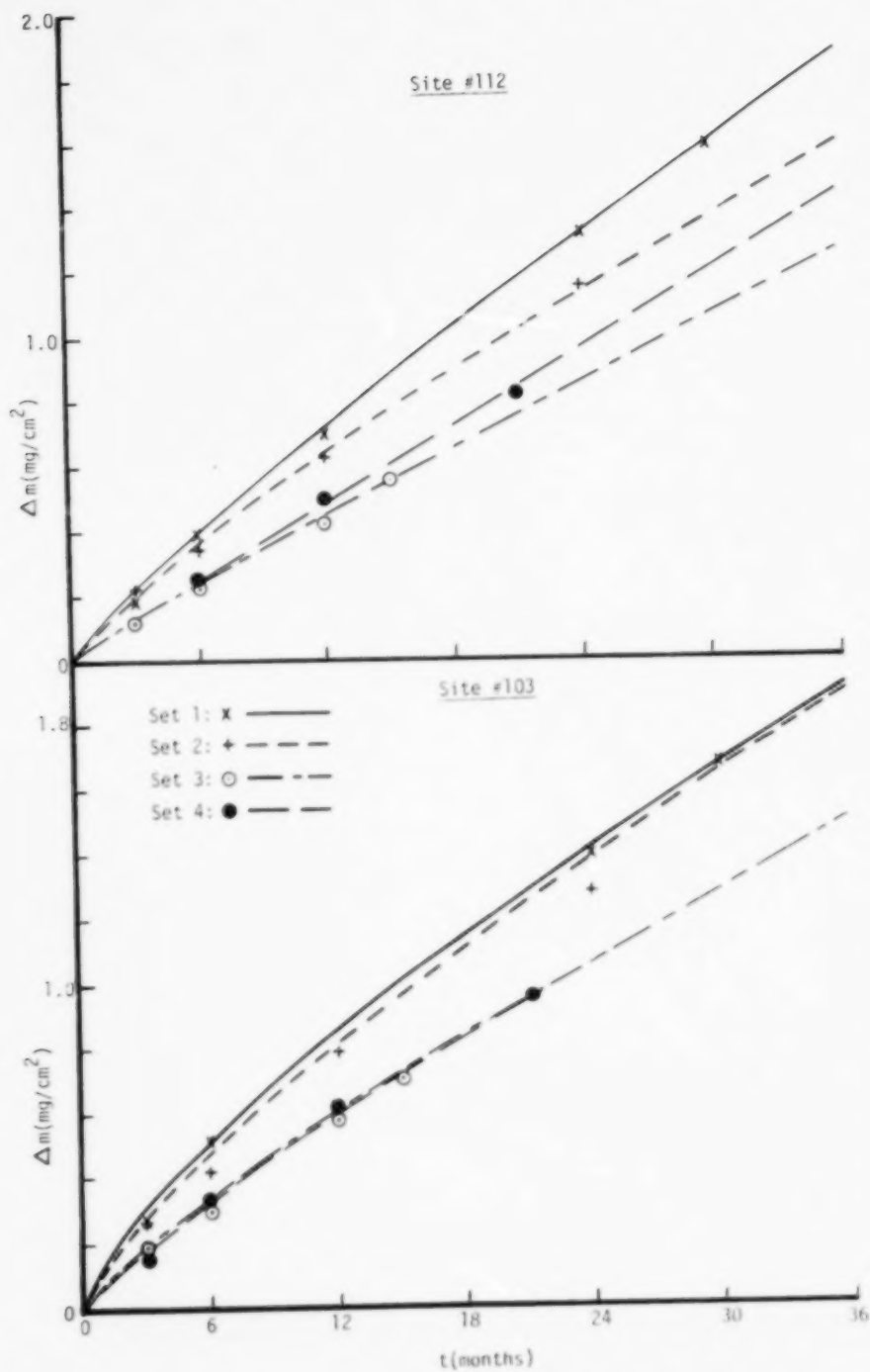


FIGURE 5. WEIGHT LOSS FOR FOUR SETS OF GALVANIZED STEEL AT SITES #103 AND 112.

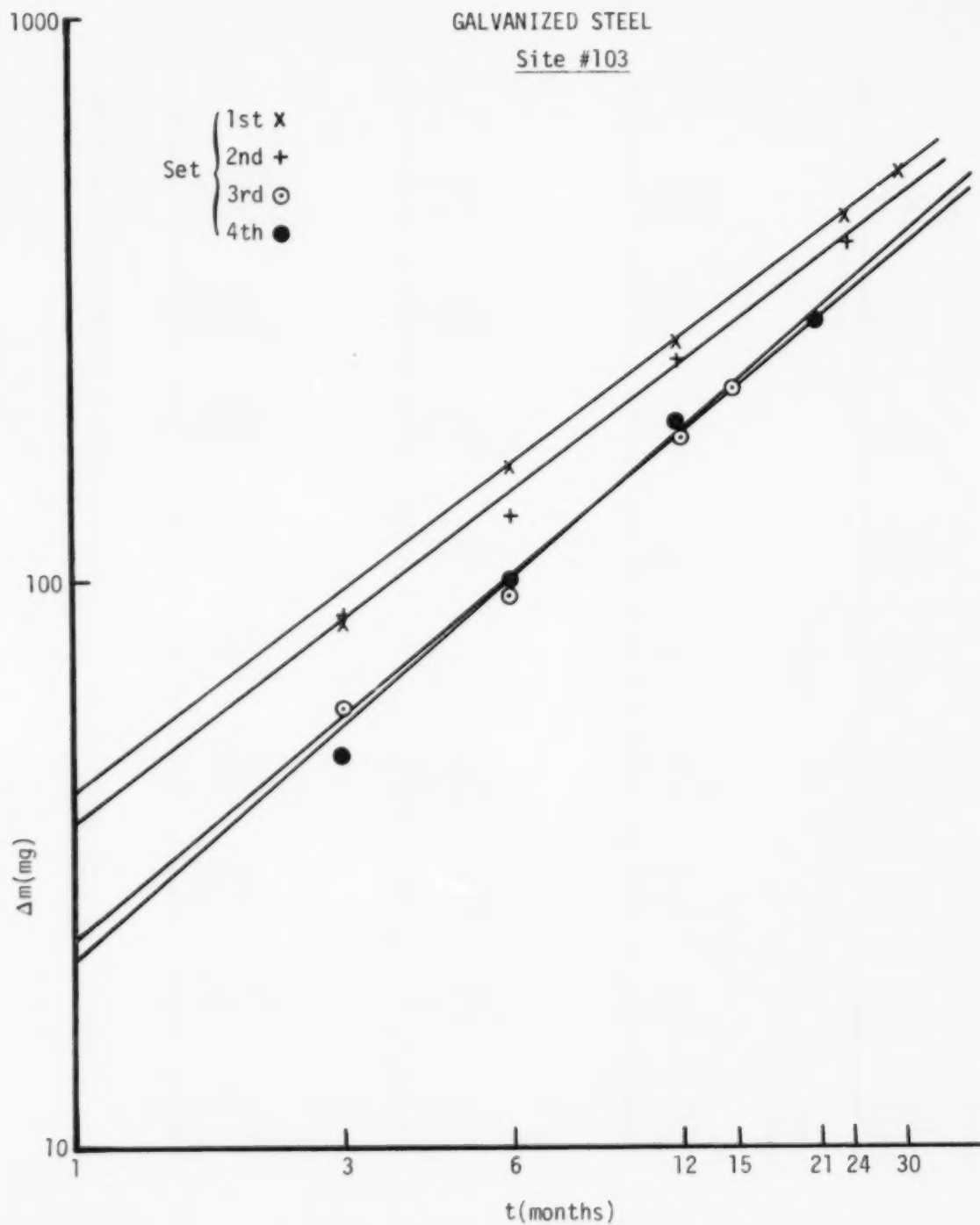


FIGURE 6. LOG-LOG PLOT OF WEIGHT LOSS OF GALVANIZED STEEL AT SITE #103 AS A FUNCTION OF TIME.

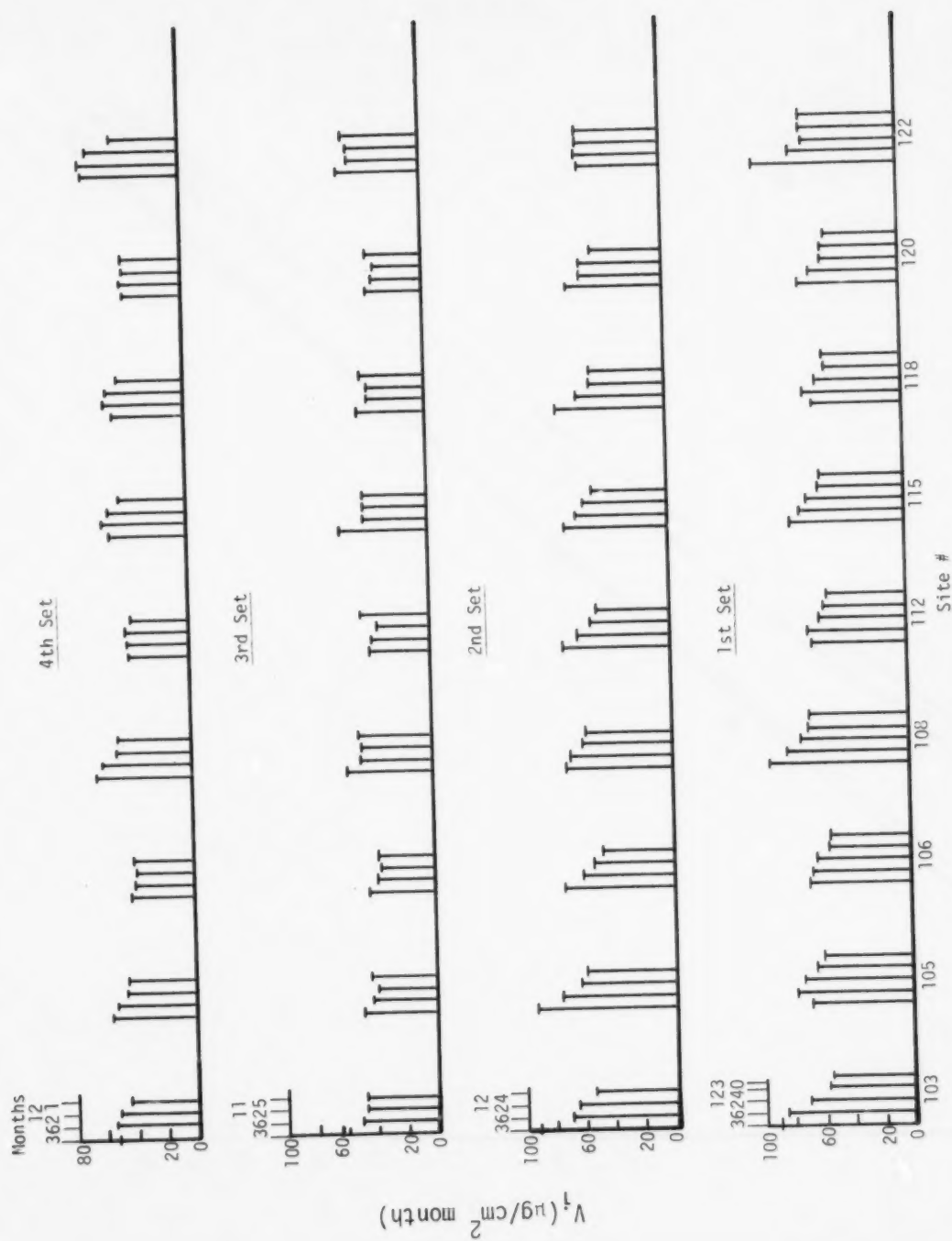


FIGURE 7. INTEGRAL CORROSION RATES V_i FOR FOUR SETS OF GALVANIZED STEEL AT THE NINE TEST SITES.

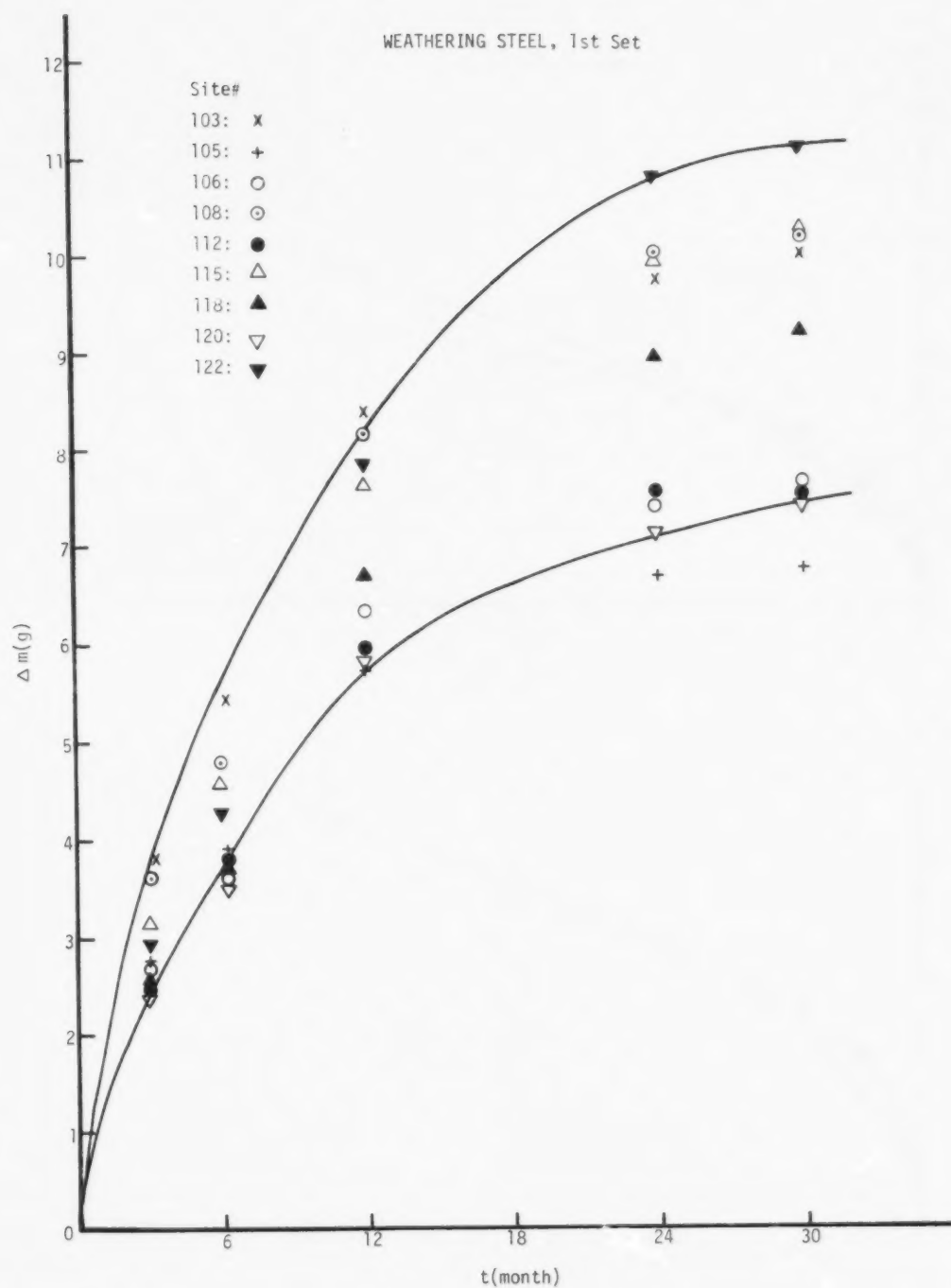


FIGURE 8. WEIGHT LOSS OF WEATHERING STEEL, FIRST SET, AT THE NINE TEST SITES.

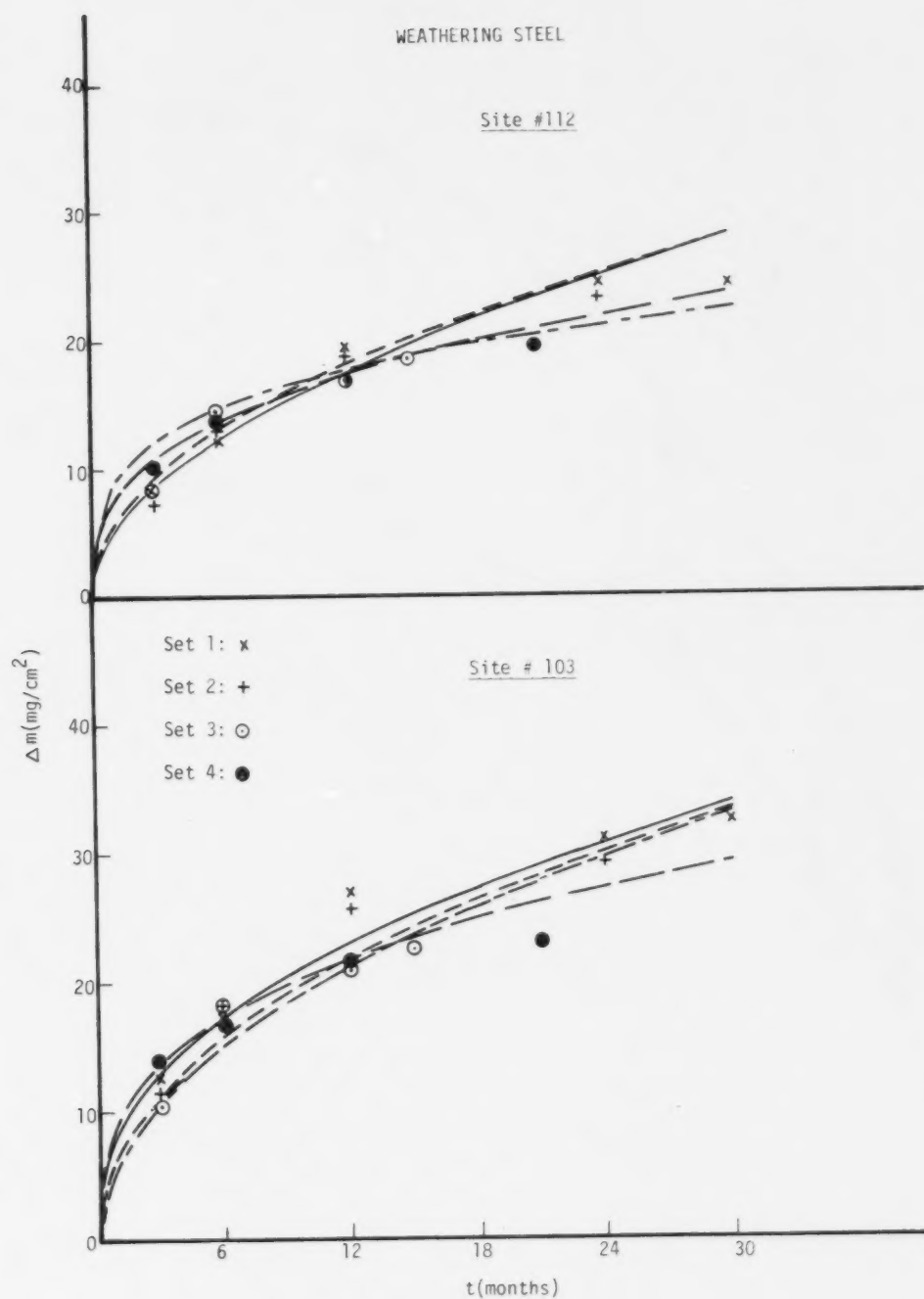


FIGURE 9. WEIGHT LOSS OF FOUR SETS OF WEATHERING STEEL AT SITES #103 and 112.

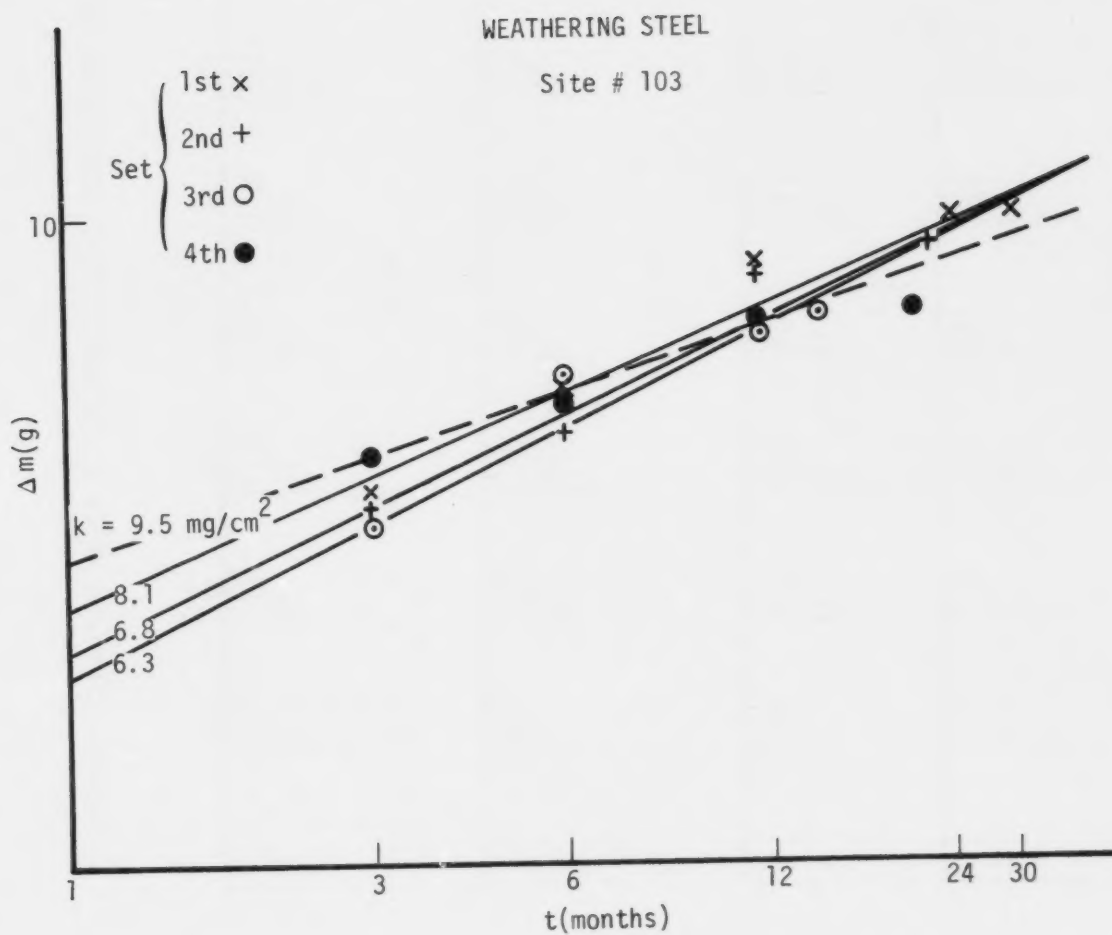


FIGURE 10. LOG-LOG PLOT OF WEIGHT LOSS OF WEATHERING STEEL AT SITE #103 AS A FUNCTION OF TIME.



FIGURE 11. INTEGRAL CORROSION RATES V_i FOR FOUR SETS OF WEATHERING STEEL AT THE NINE TEST SITES.

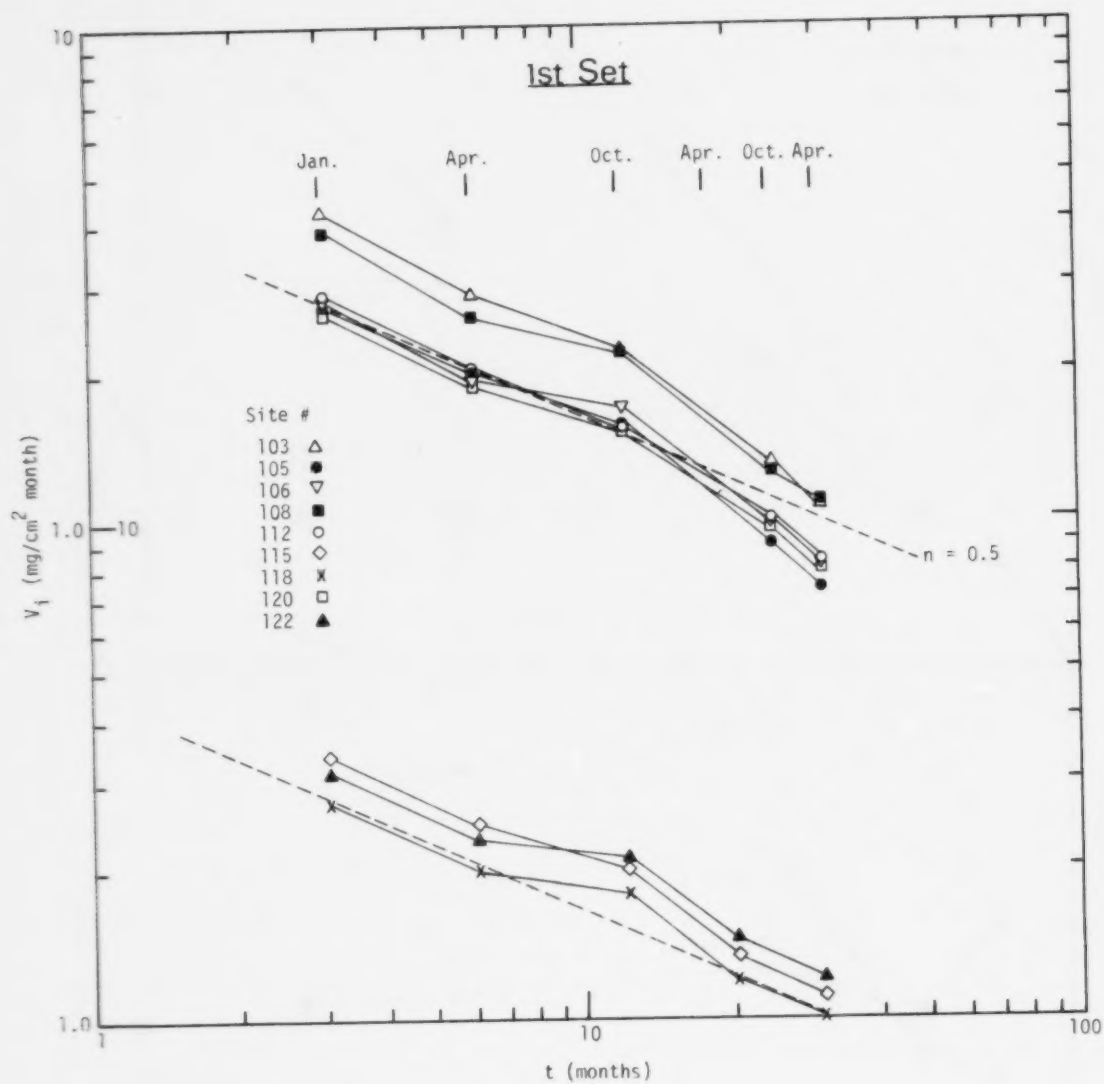


FIGURE 12. LOG-LOG PLOT OF INTEGRAL CORROSION RATES FOR THE FIRST SET OF WEATHERING STEEL AT ALL TEST SITES AS A FUNCTION OF TIME.

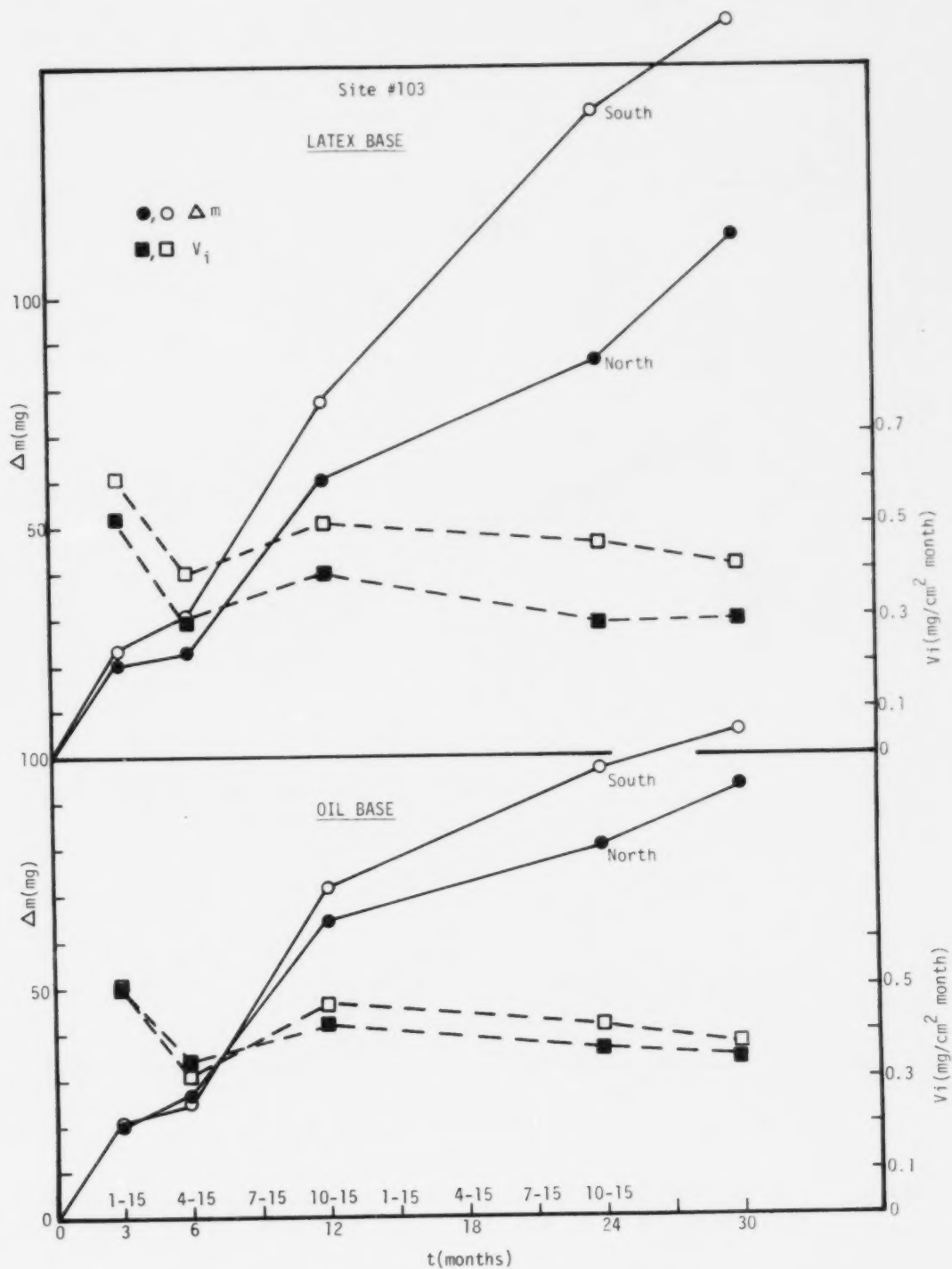


FIGURE 13. WEIGHT LOSS AND INTEGRAL CORROSION RATES FOR HOUSE PAINT AT SITE #103.

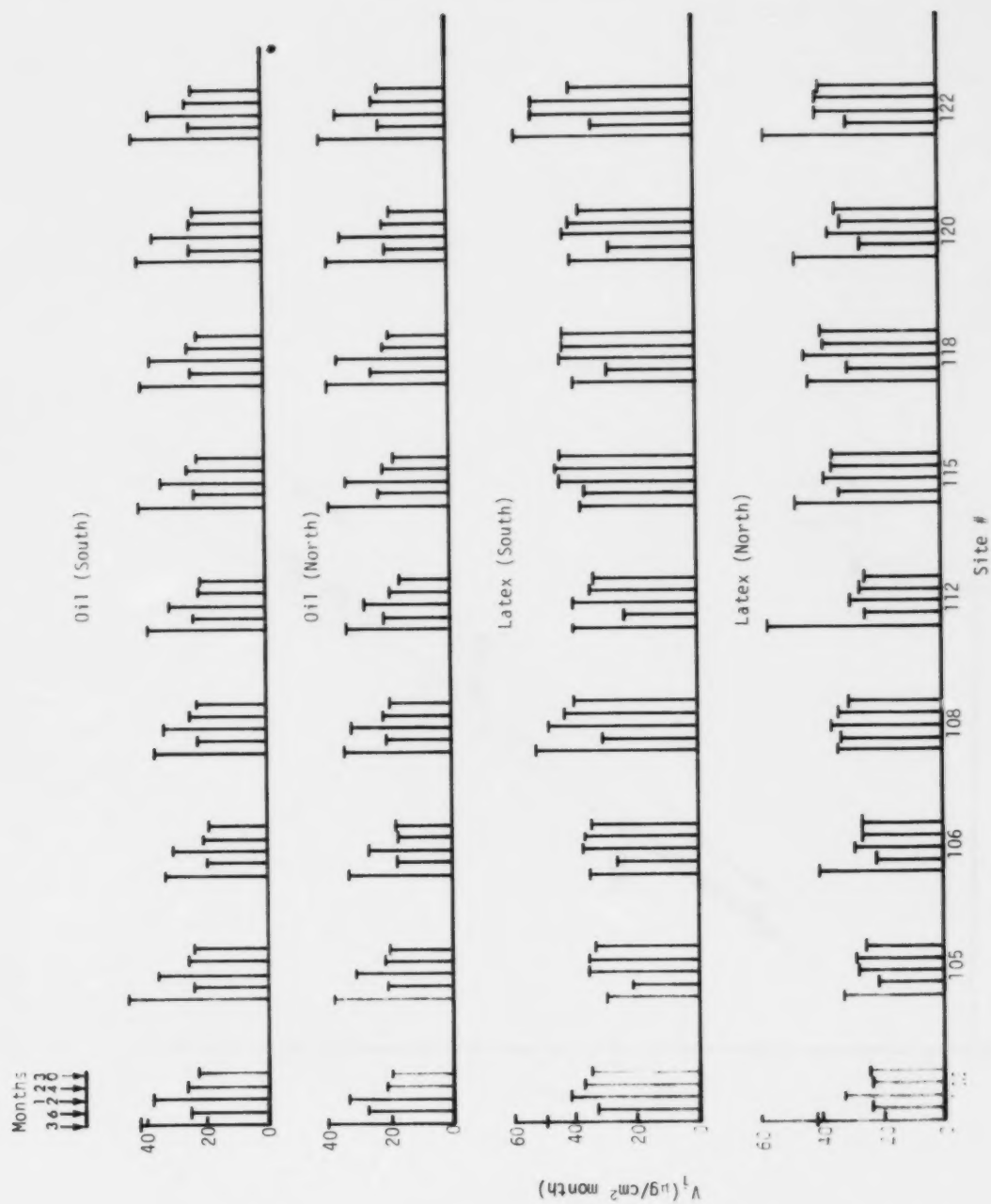


FIGURE 14. INTEGRAL CORROSION RATES FOR HOUSE PAINT AT THE NINE TEST SITES.

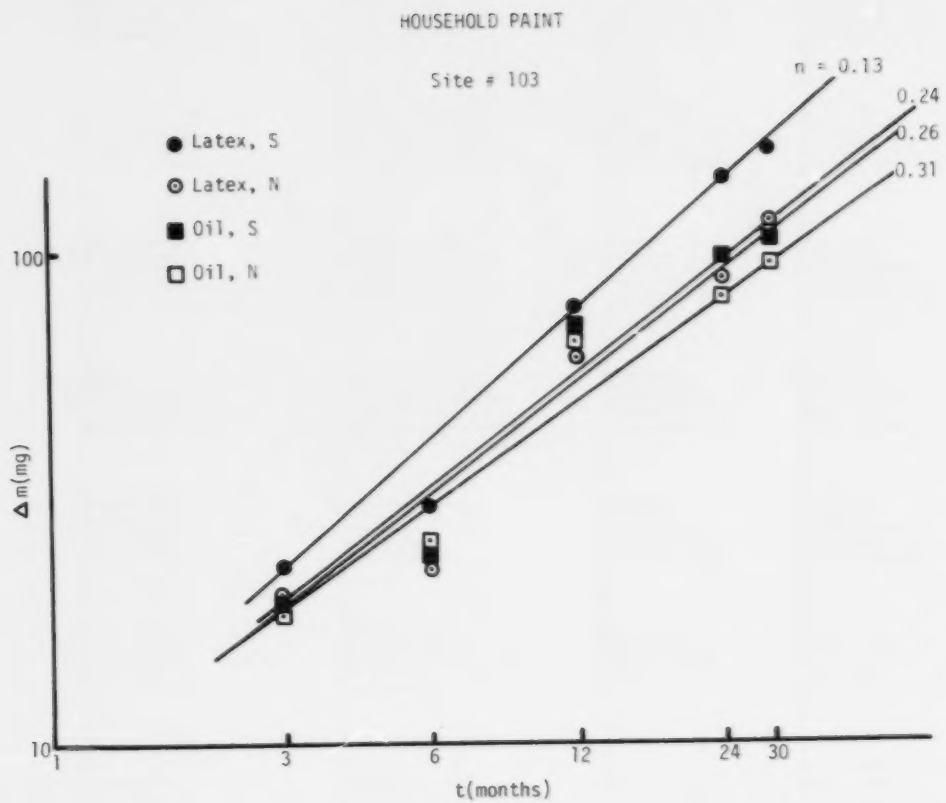


FIGURE 15. LOG-LOG PLOT OF WEIGHT LOSS OF HOUSE PAINT AT SITE #103 AS A FUNCTION OF TIME.

Marble

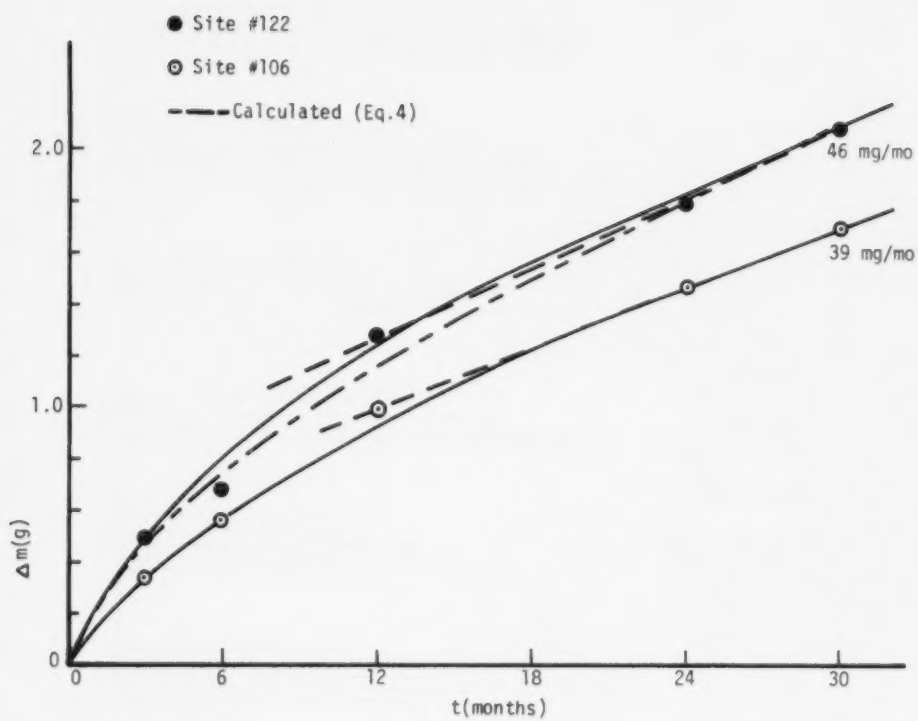


FIGURE 16. WEIGHT LOSS OF MARBLE AT SITES #106 AND #122 OVER A THIRTY-MONTH PERIOD

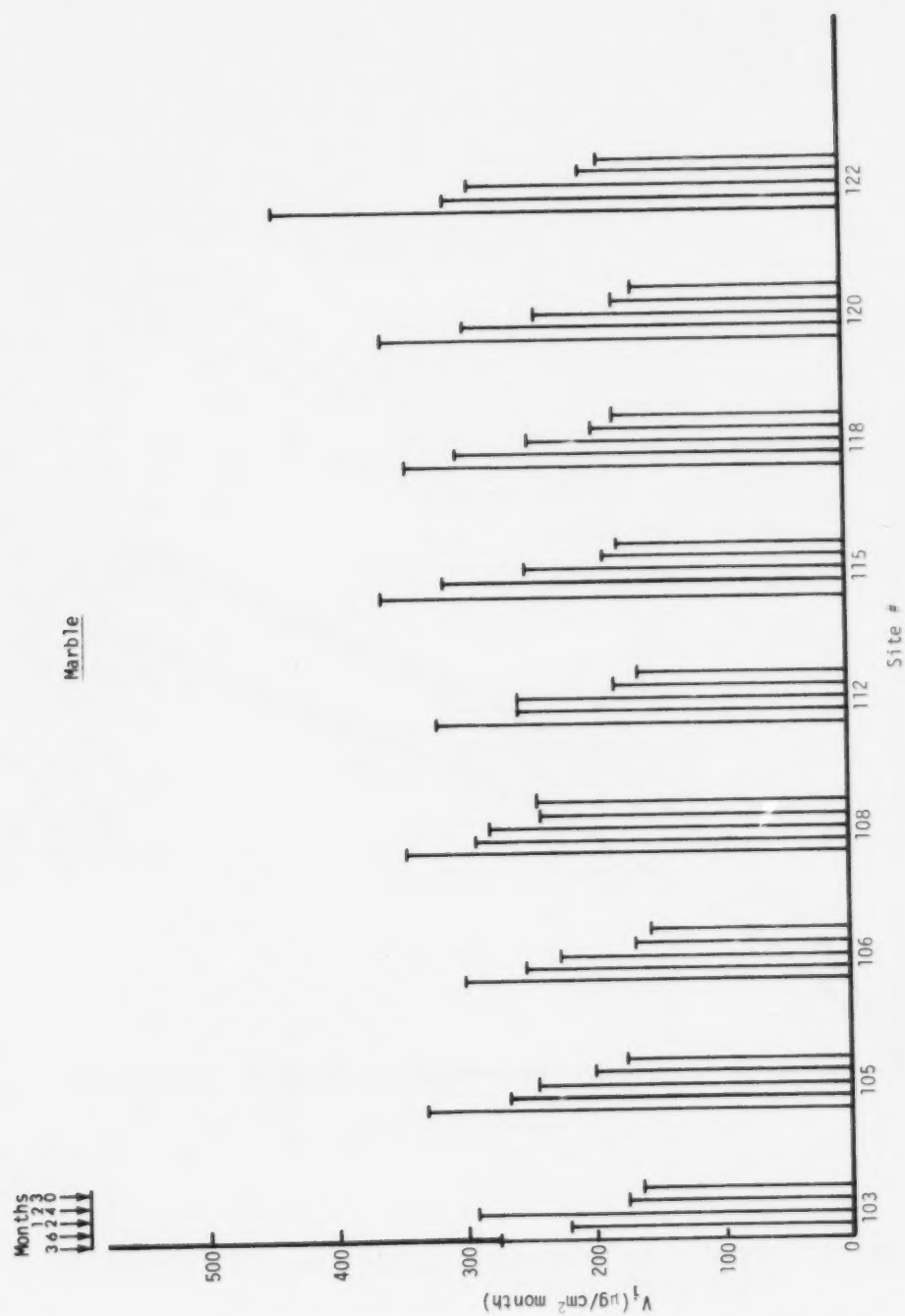


FIGURE 17. INTEGRAL CORROSION RATES V_i FOR MARBLE AT NINE TEST SITES.

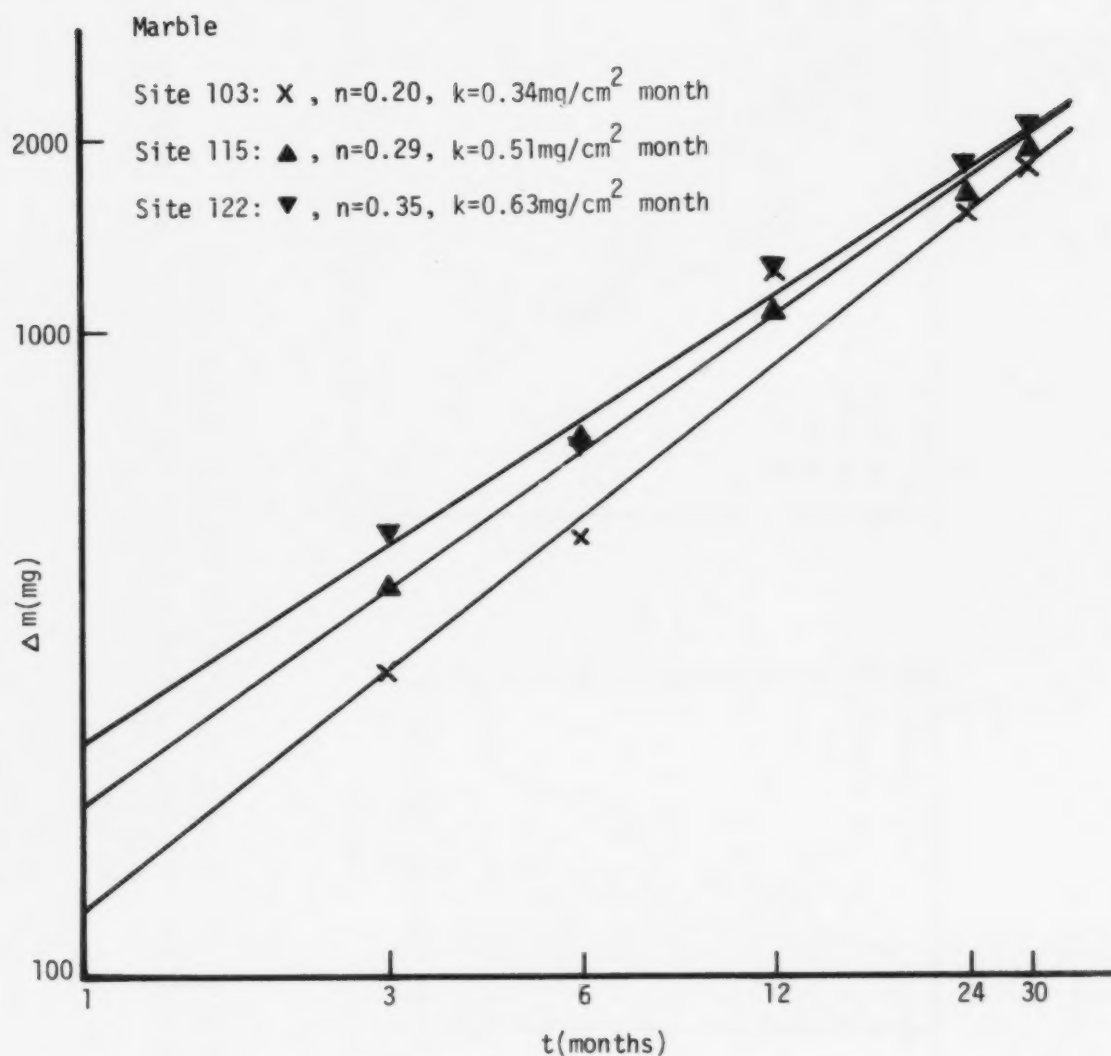


FIGURE 18. LOG Δm -LOG TIME PLOT FOR MARBLE AT SITES #103, 115, AND 122.

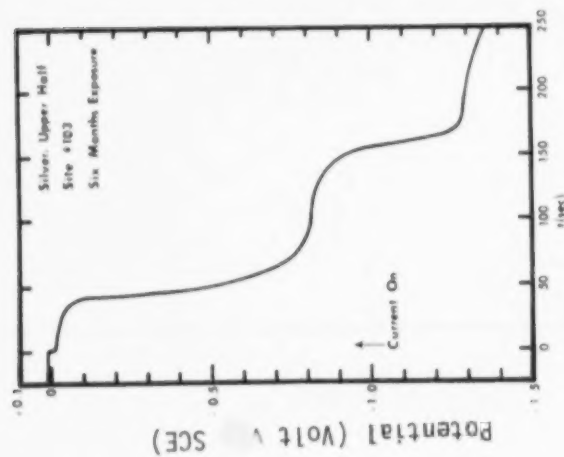


FIGURE 19

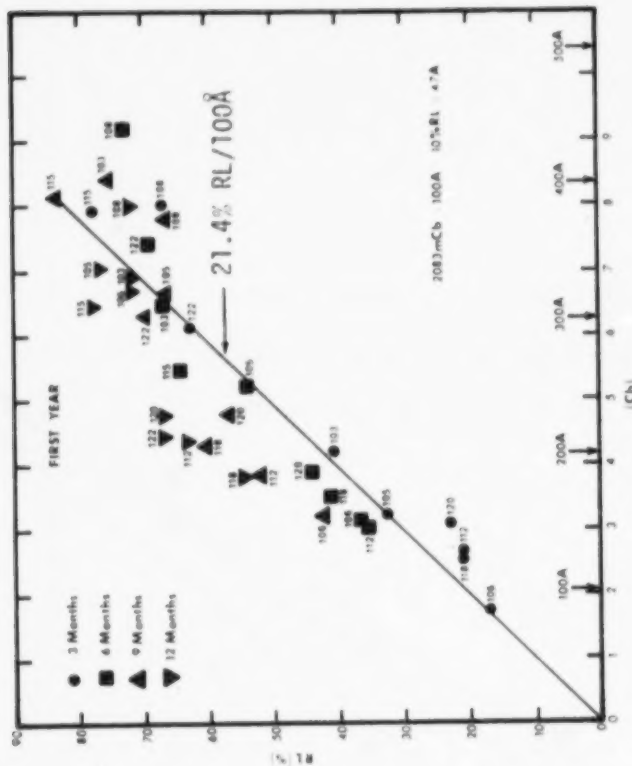


FIGURE 20

FIGURE 19. CATHODIC REDUCTION OF TARNISH FILM ON SILVER.

FIGURE 20. RELATIONSHIP BETWEEN REFLECTANCE LOSS RL (%) AND AMOUNT OF ELECTRICITY (Cb) USED TO REDUCE TARNISH FILM ON SILVER EXPOSED AT NINE SITES DURING FIRST YEAR OF EXPOSURE.

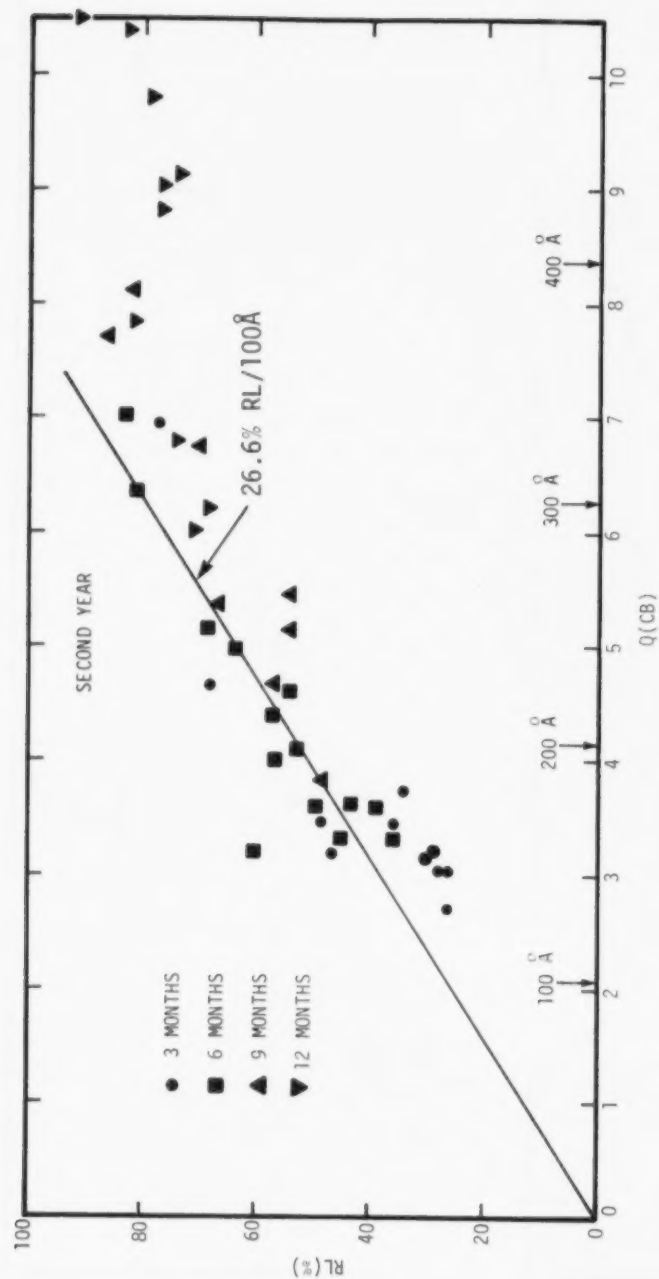


FIGURE 21. RELATIONSHIP BETWEEN REFLECTANCE LOSS RL (%) AND AMOUNT OF ELECTRICITY (Cb) USED TO REDUCE TARNISH FILM ON SILVER EXPOSED AT NINE SITES DURING SECOND YEAR OF EXPOSURE.

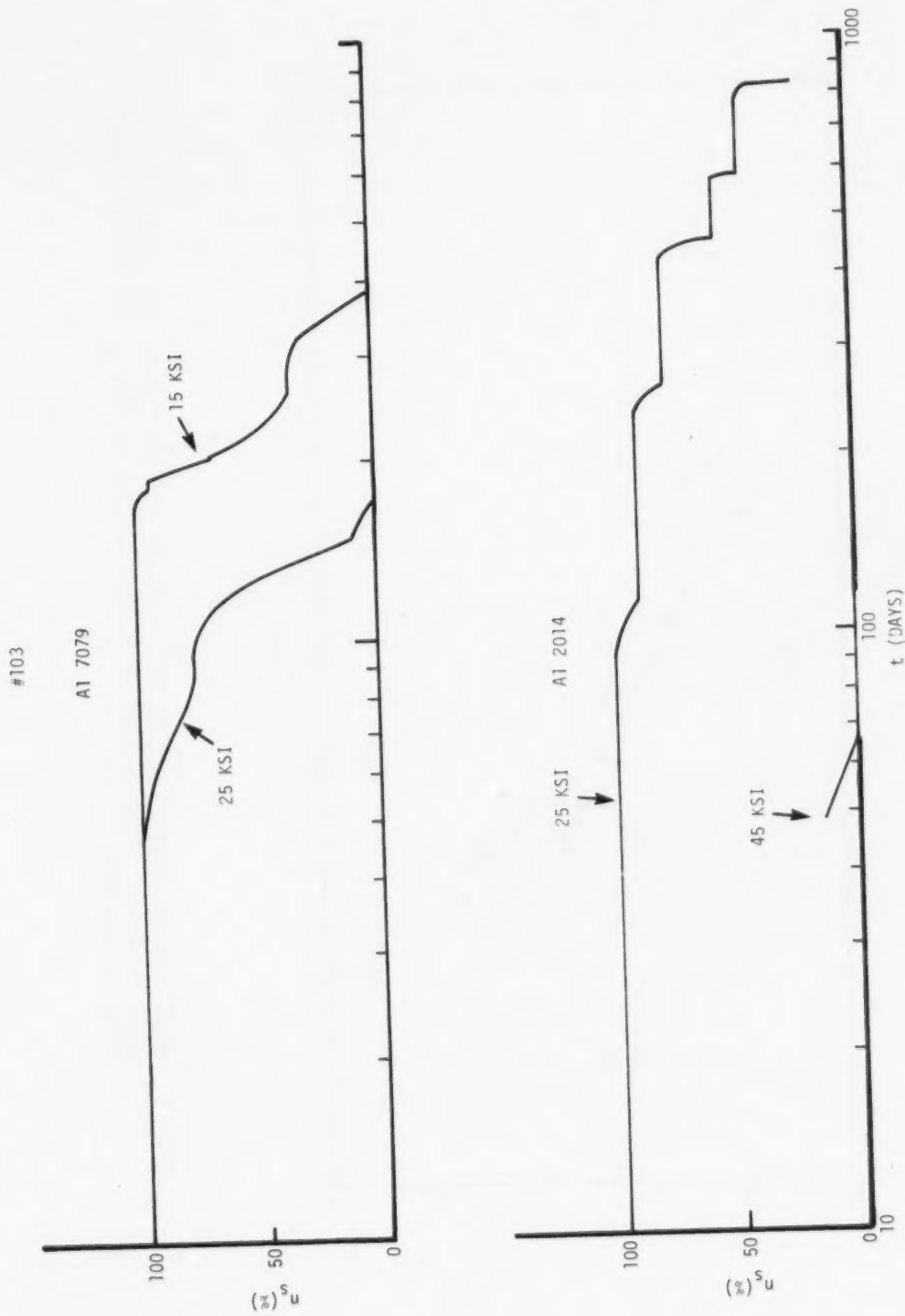


FIGURE 22a. PERCENT OF A1 TENSION SAMPLES SURVIVING (n_s) AS A FUNCTION OF TIME FOR SITE #103.

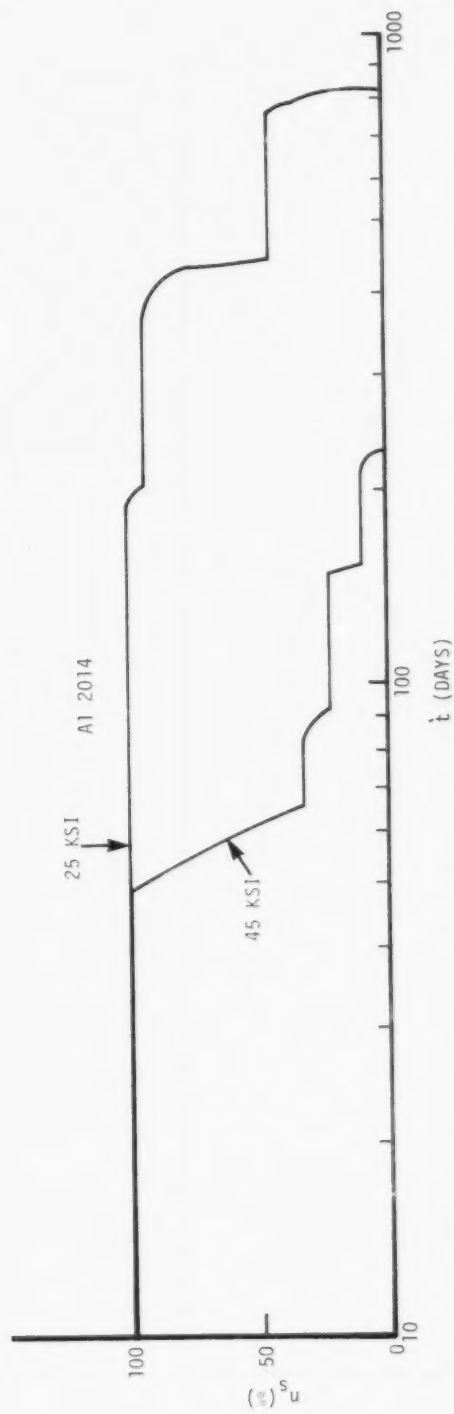
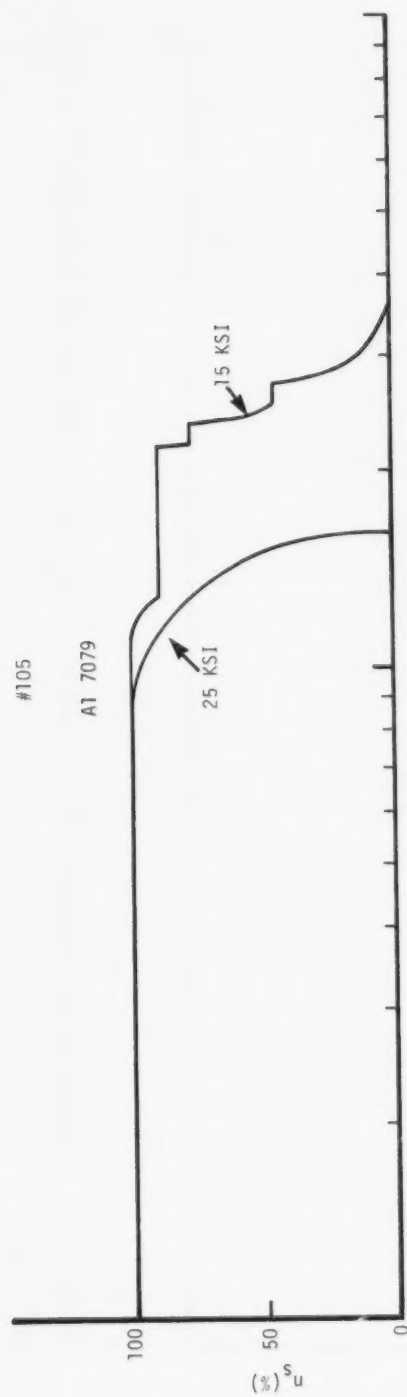


FIGURE 22b. PERCENT OF A1 TENSION SAMPLES SURVIVING (n_s) AS A FUNCTION OF TIME FOR SITE #105.

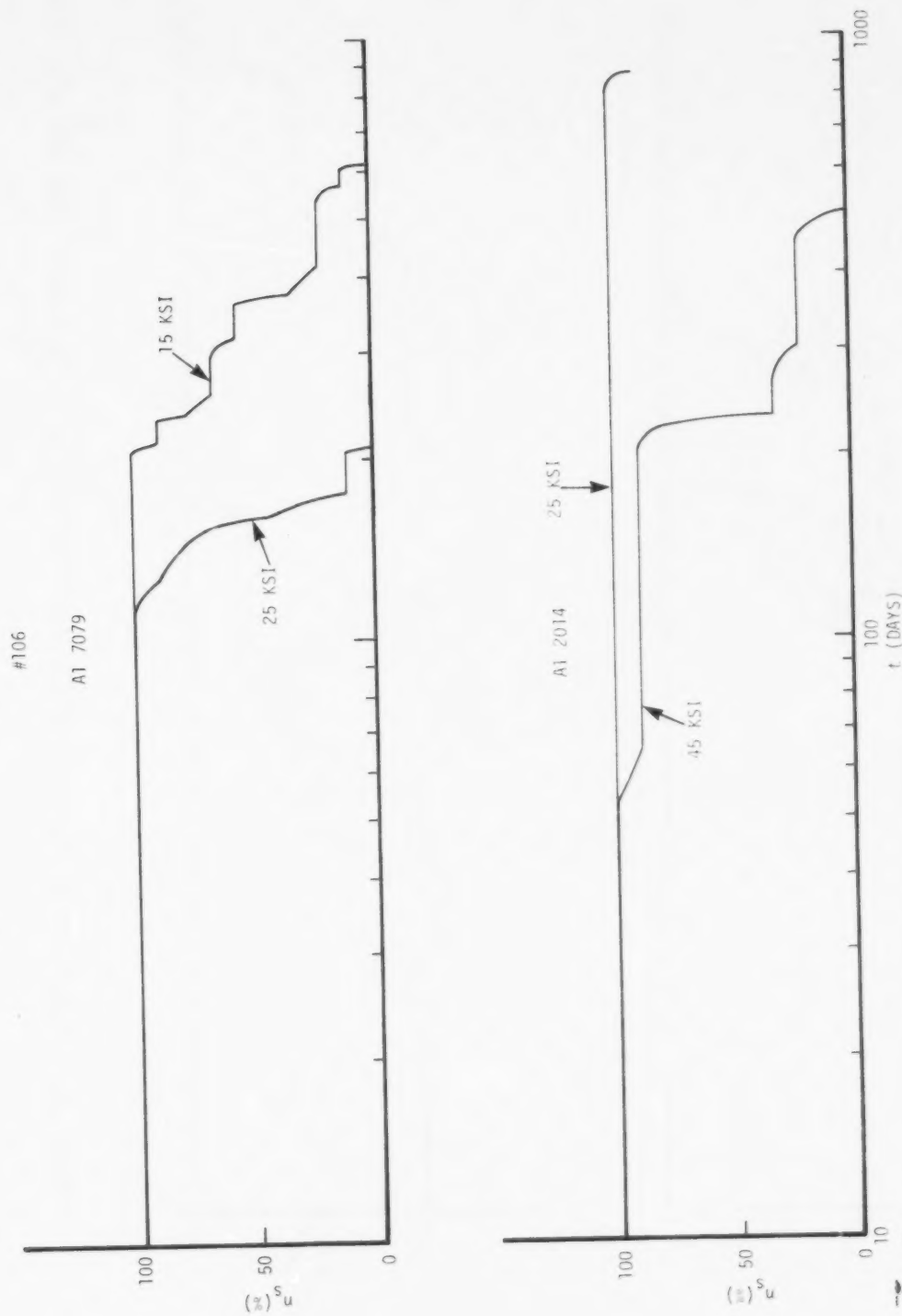


FIGURE 22c. PERCENT OF A1 TENSION SAMPLES SURVIVING (n_s) AS A FUNCTION OF TIME FOR SITE #106.

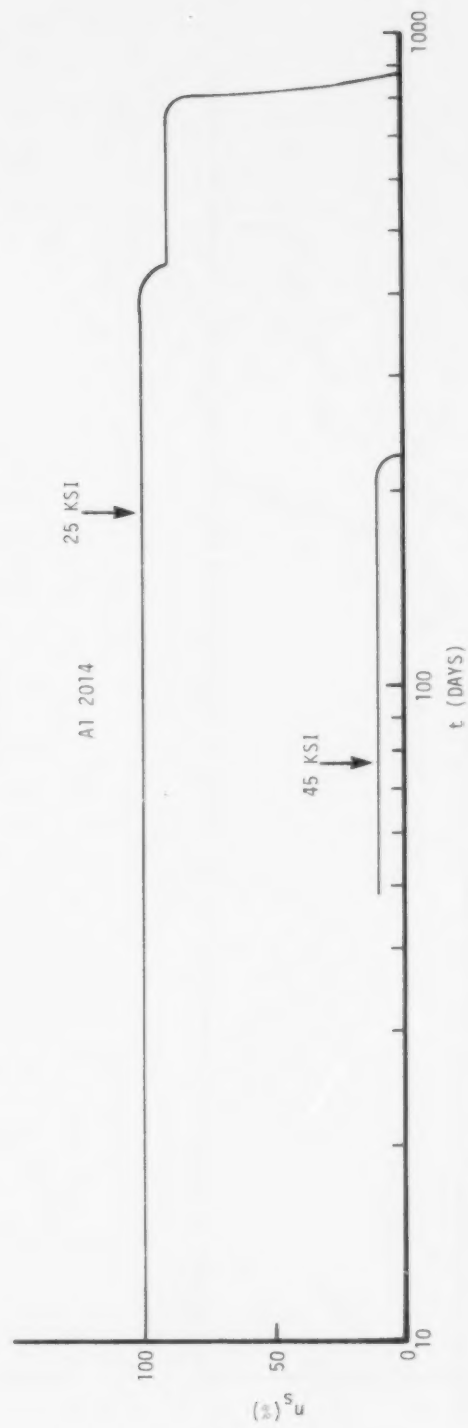
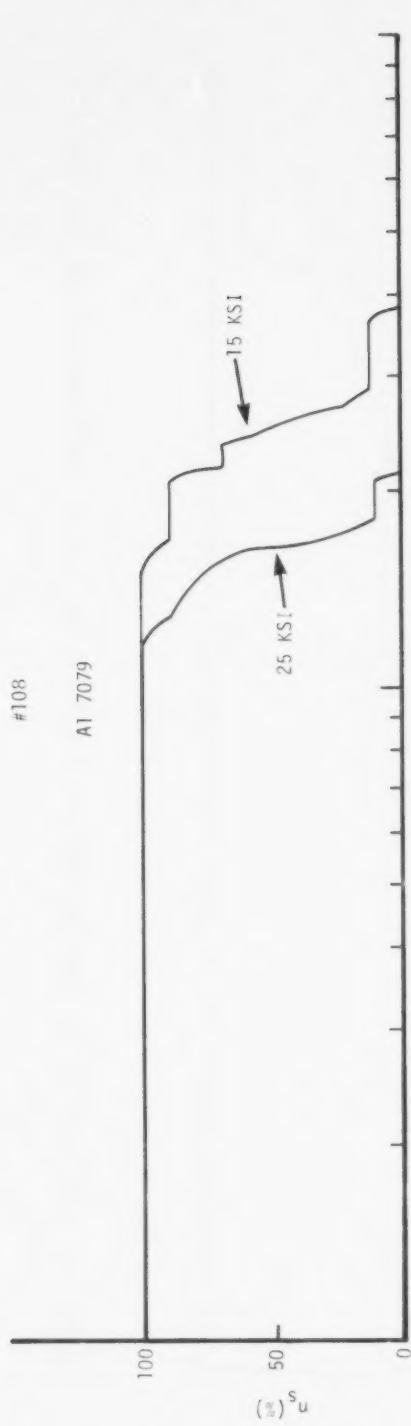


FIGURE 22d. PERCENT OF A1 TENSION SAMPLES SURVIVING (n_s) AS A FUNCTION OF TIME FOR SITE #108.

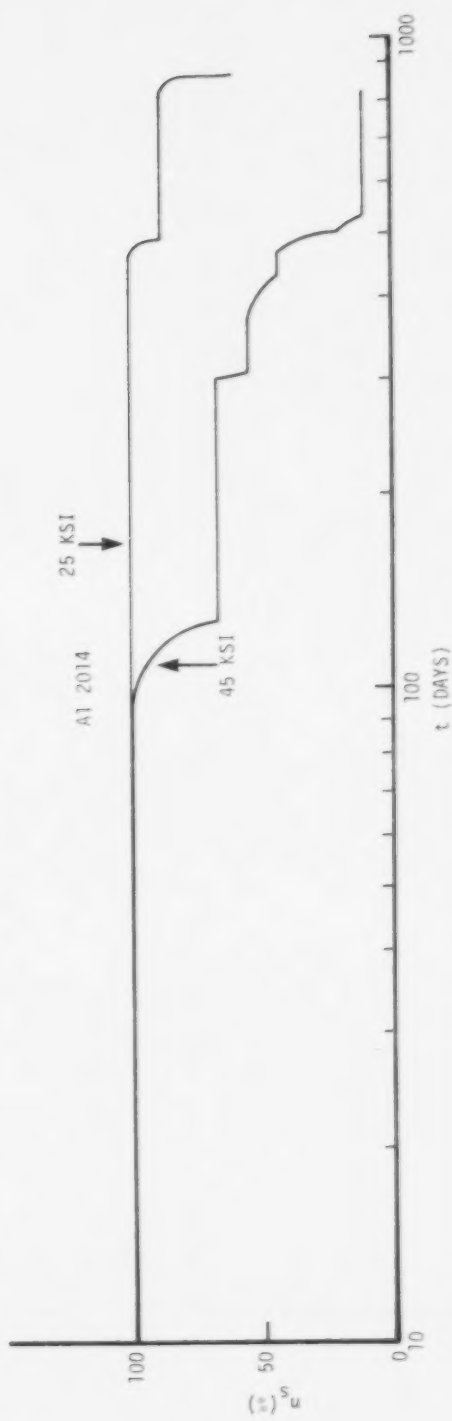
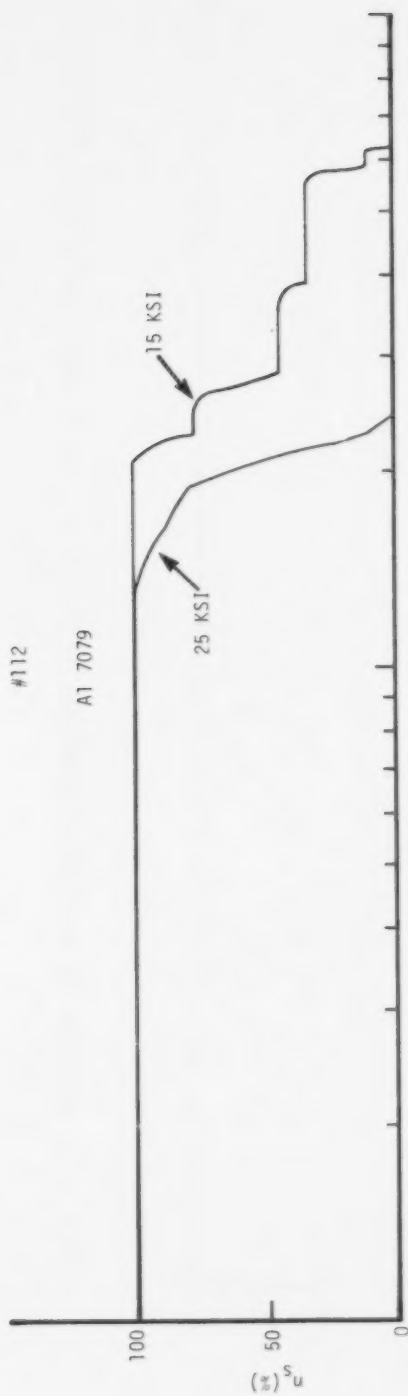


FIGURE 22e. PERCENT OF A1 TENSION SAMPLES SURVIVING (n_s) AS A FUNCTION OF TIME FOR SITE #112.

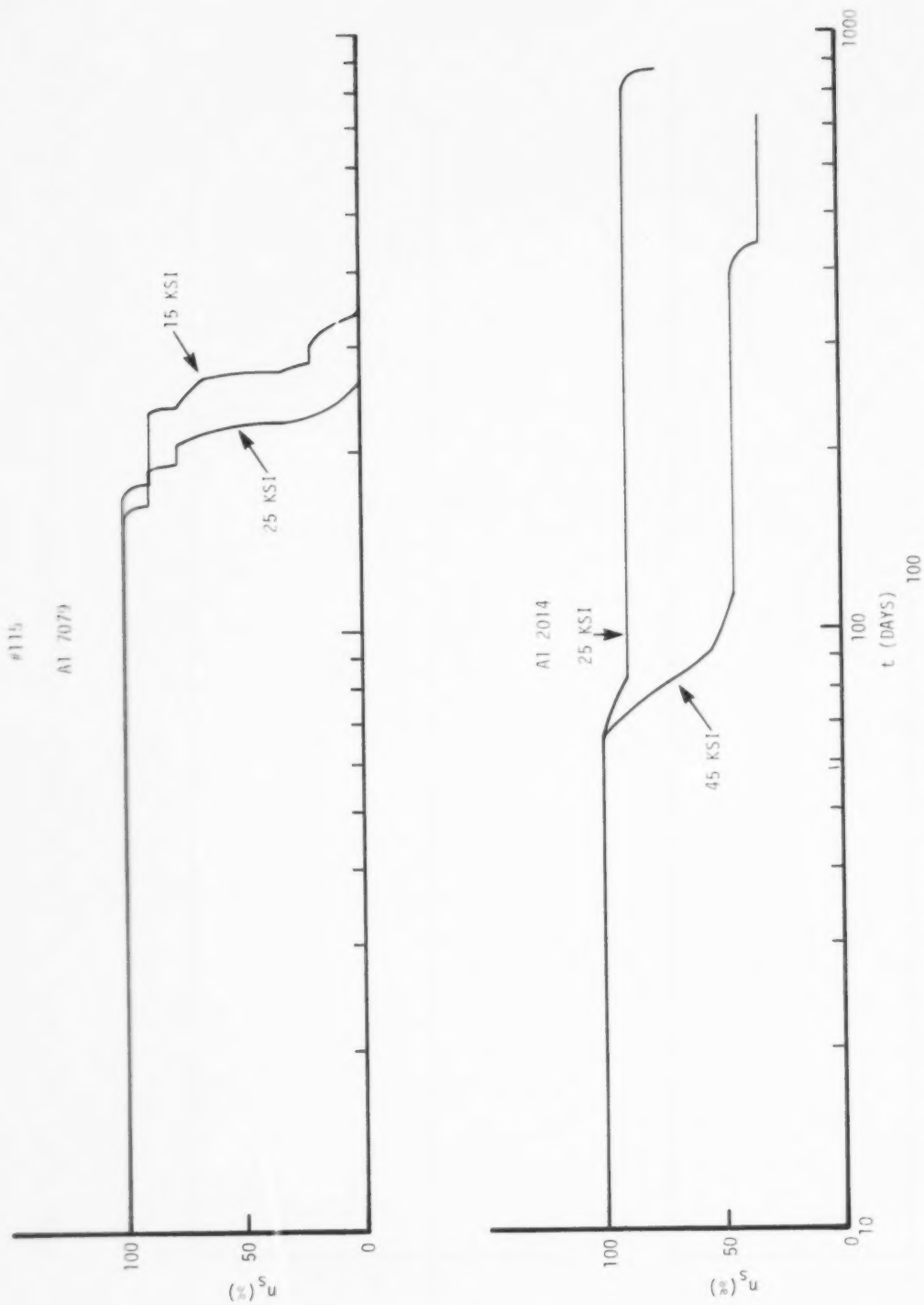


FIGURE 22f. PERCENT OF A1 TENSION SAMPLES SURVIVING (n_s) AS A FUNCTION OF TIME FOR SITE #115.

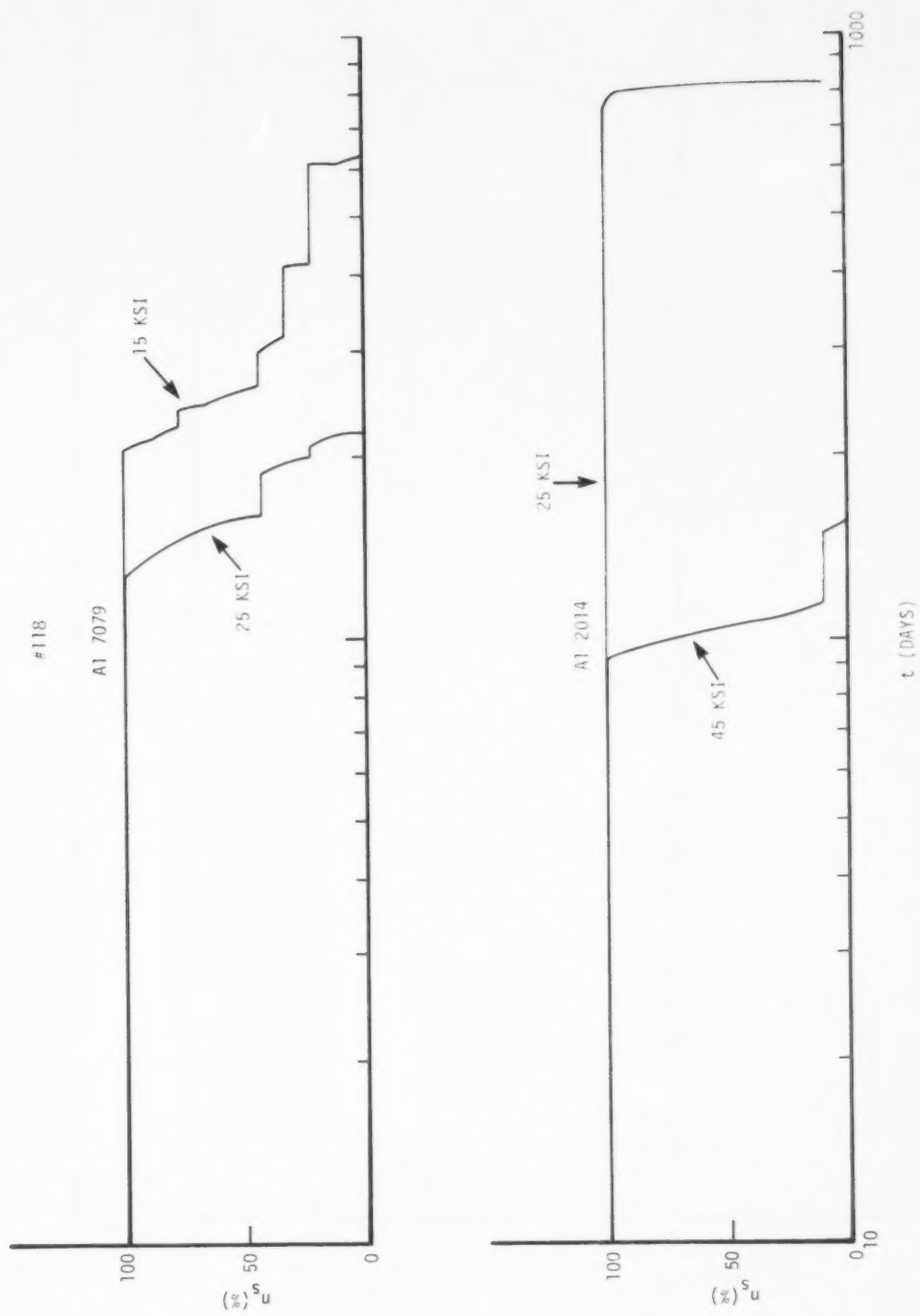


FIGURE 22g. PERCENT OF A1 TENSION SAMPLES SURVIVING (n_s) AS A FUNCTION OF TIME FOR SITE #118.

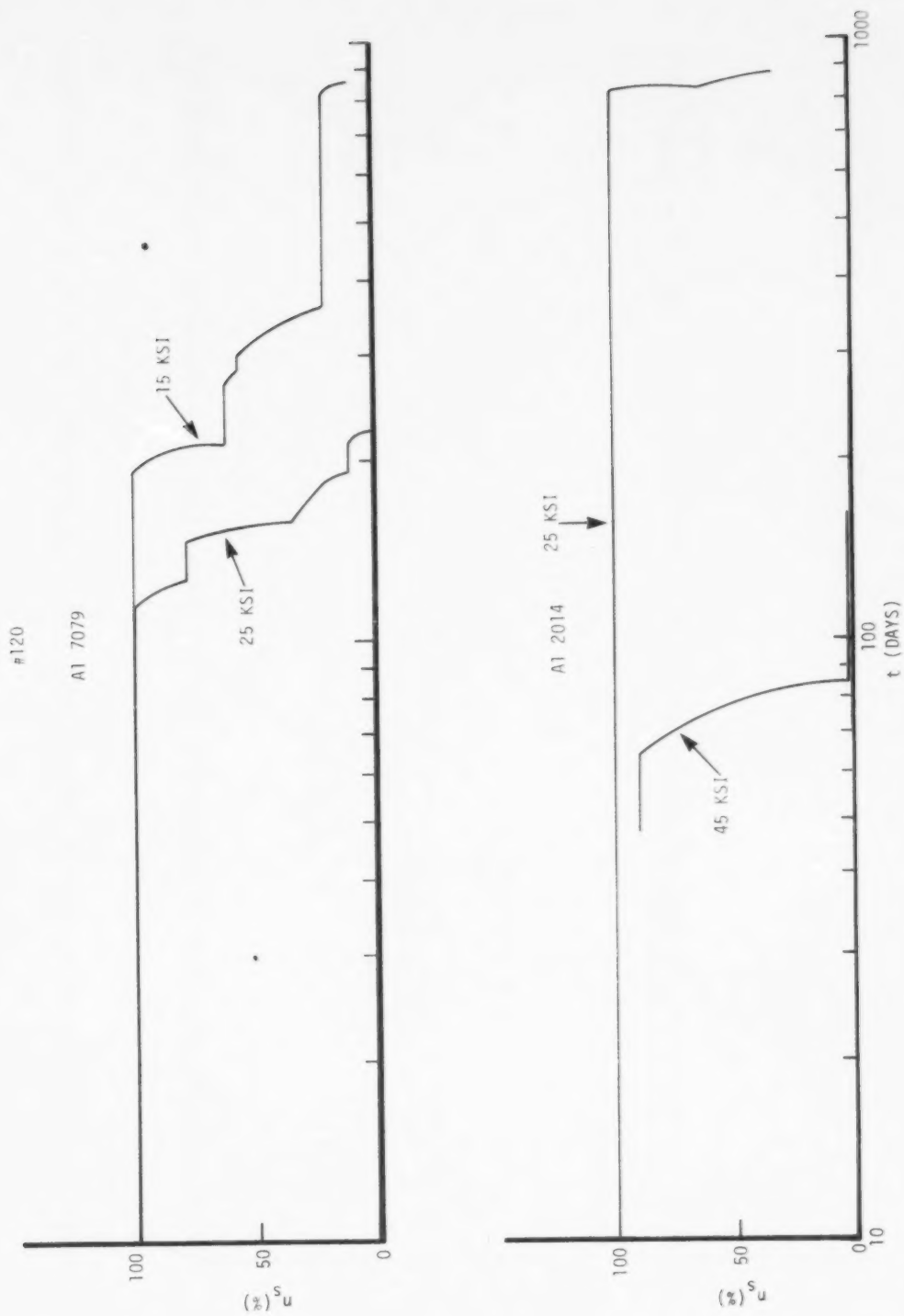


FIGURE 22h. PERCENT OF A1 TENSION SAMPLES SURVIVING (n_s) AS A FUNCTION OF TIME FOR SITE #120.

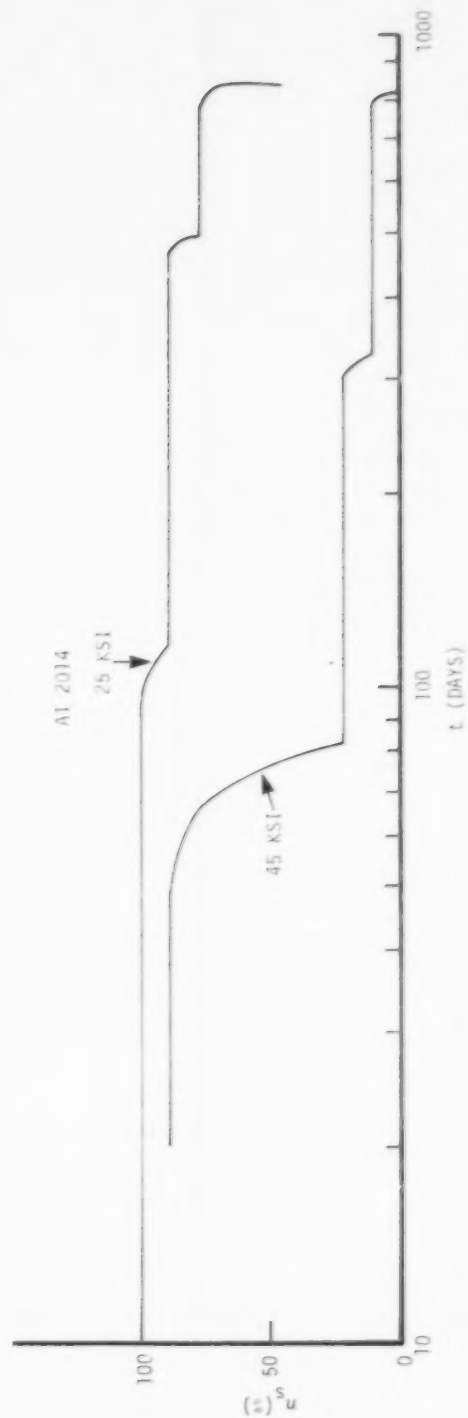
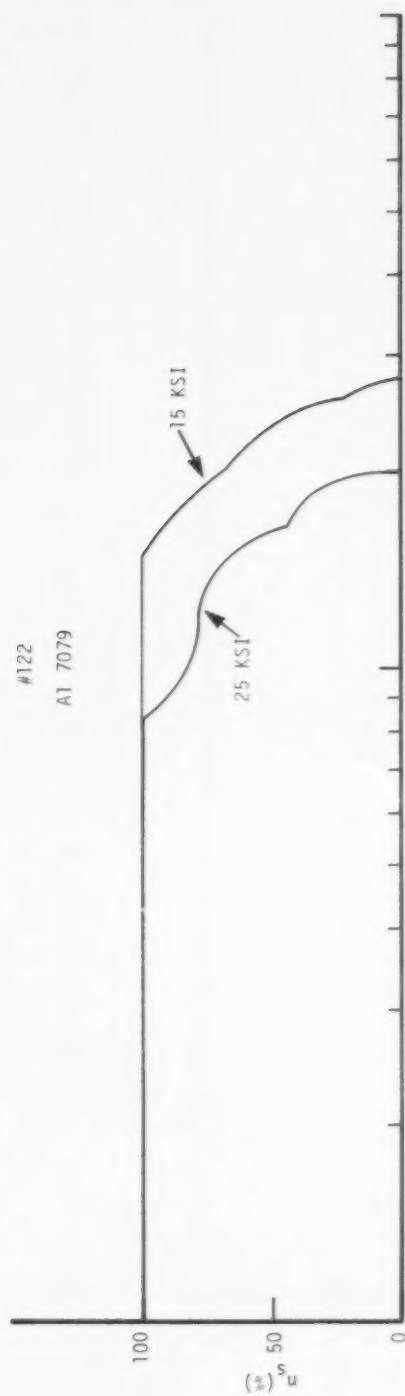


FIGURE 22i. PERCENT OF A1 TENSION SAMPLES SURVIVING (n_s) AS A FUNCTION OF TIME FOR SITE #122.

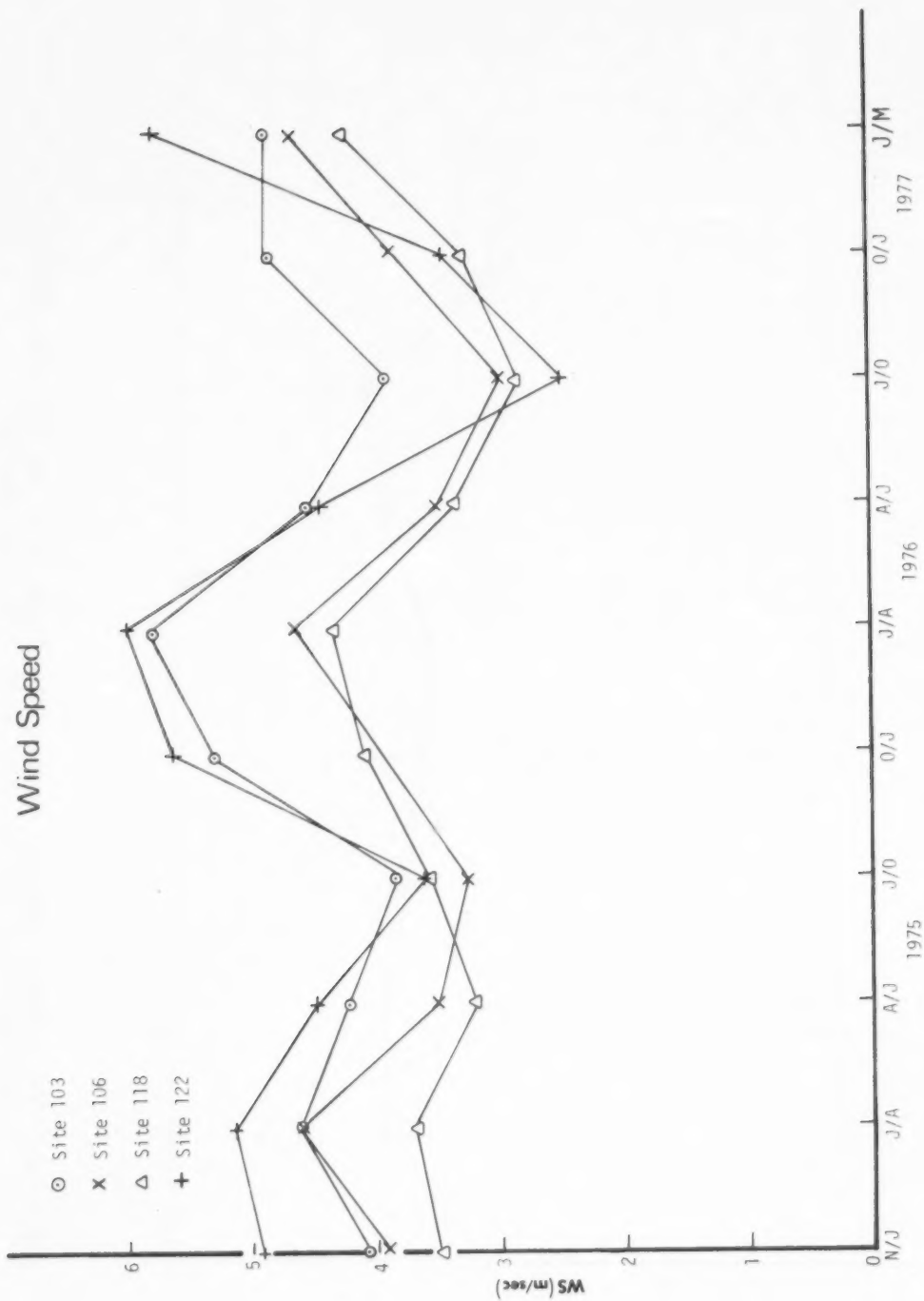


FIGURE 23a. THREE-MONTH AVERAGES OF WIND SPEED (m/s) FOR THE TIME BETWEEN NOV. 10, 1974 AND MARCH 31, 1977 AT SITES #103, 106, 118 and 122.

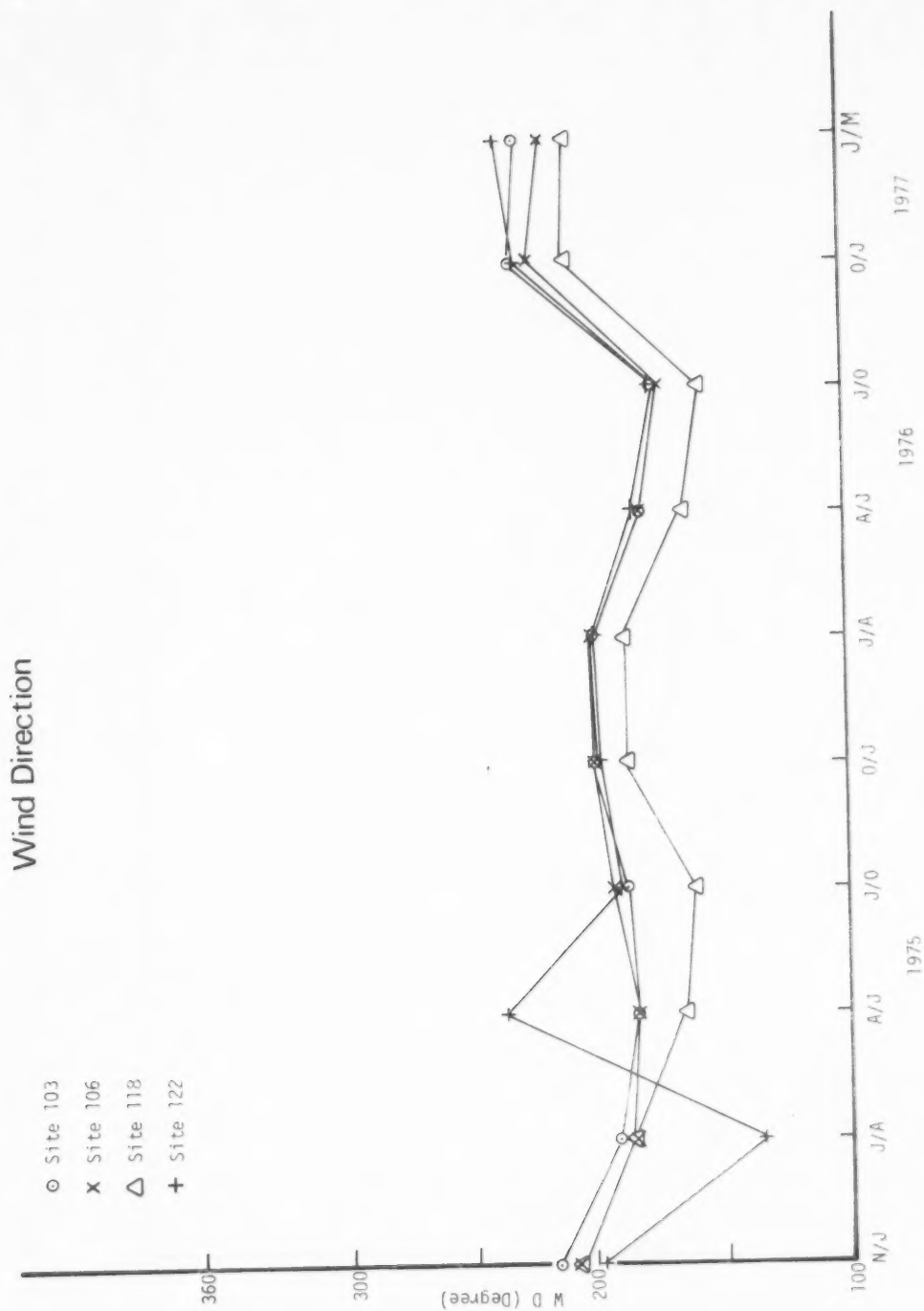


FIGURE 23b. THREE-MONTH AVERAGES OF WIND DIRECTION (deg) FOR THE TIME BETWEEN NOV. 10, 1974 AND MARCH 31, 1977 AT SITES #103, 106, 118, AND 122.

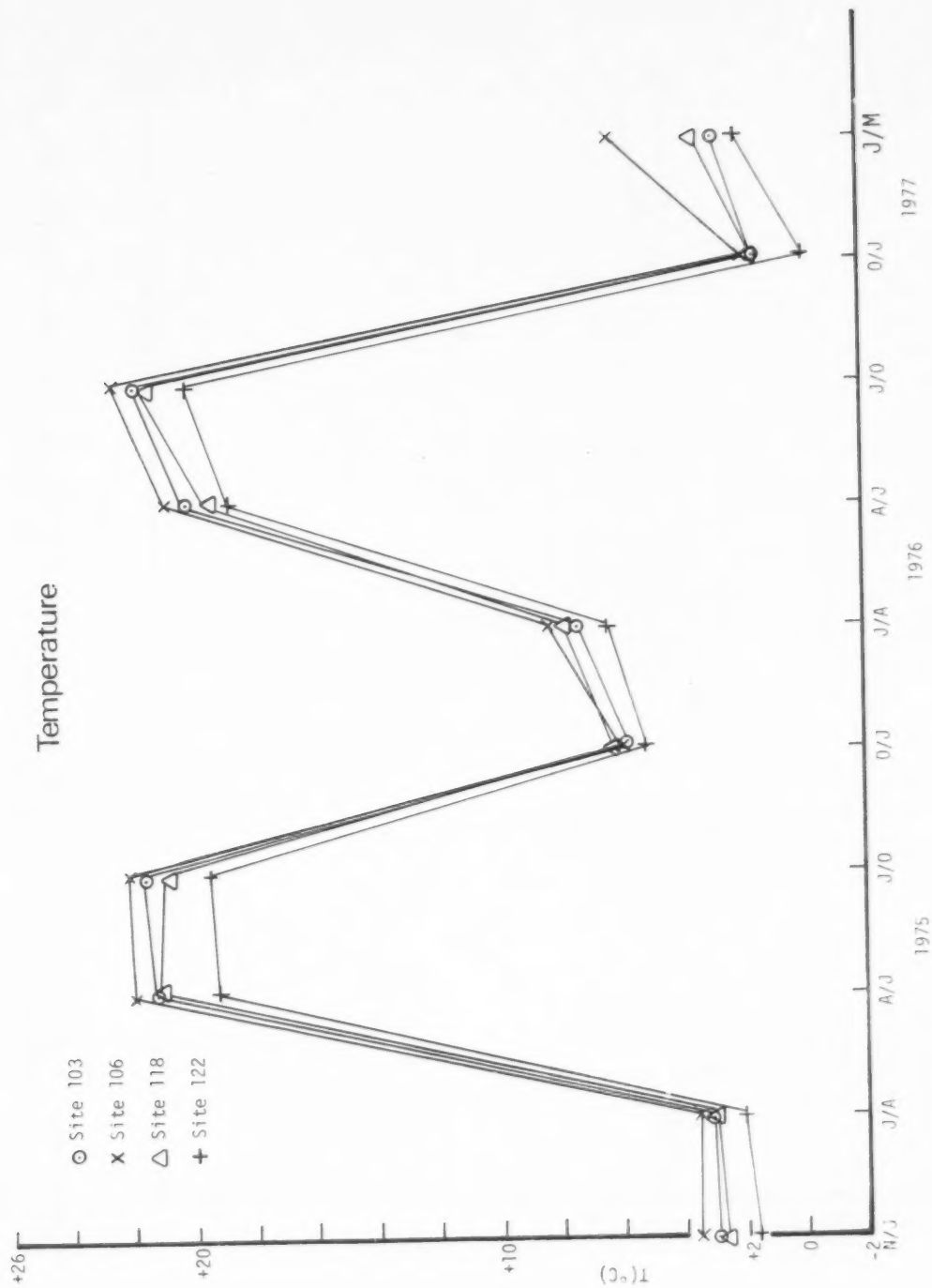


FIGURE 23c. THREE-MONTH AVERAGES OF TEMPERATURE (deg C) FOR THE TIME BETWEEN NOV. 10, 1974 AND MARCH 31, 1977 AT SITES #103, 106, 118 AND 122.

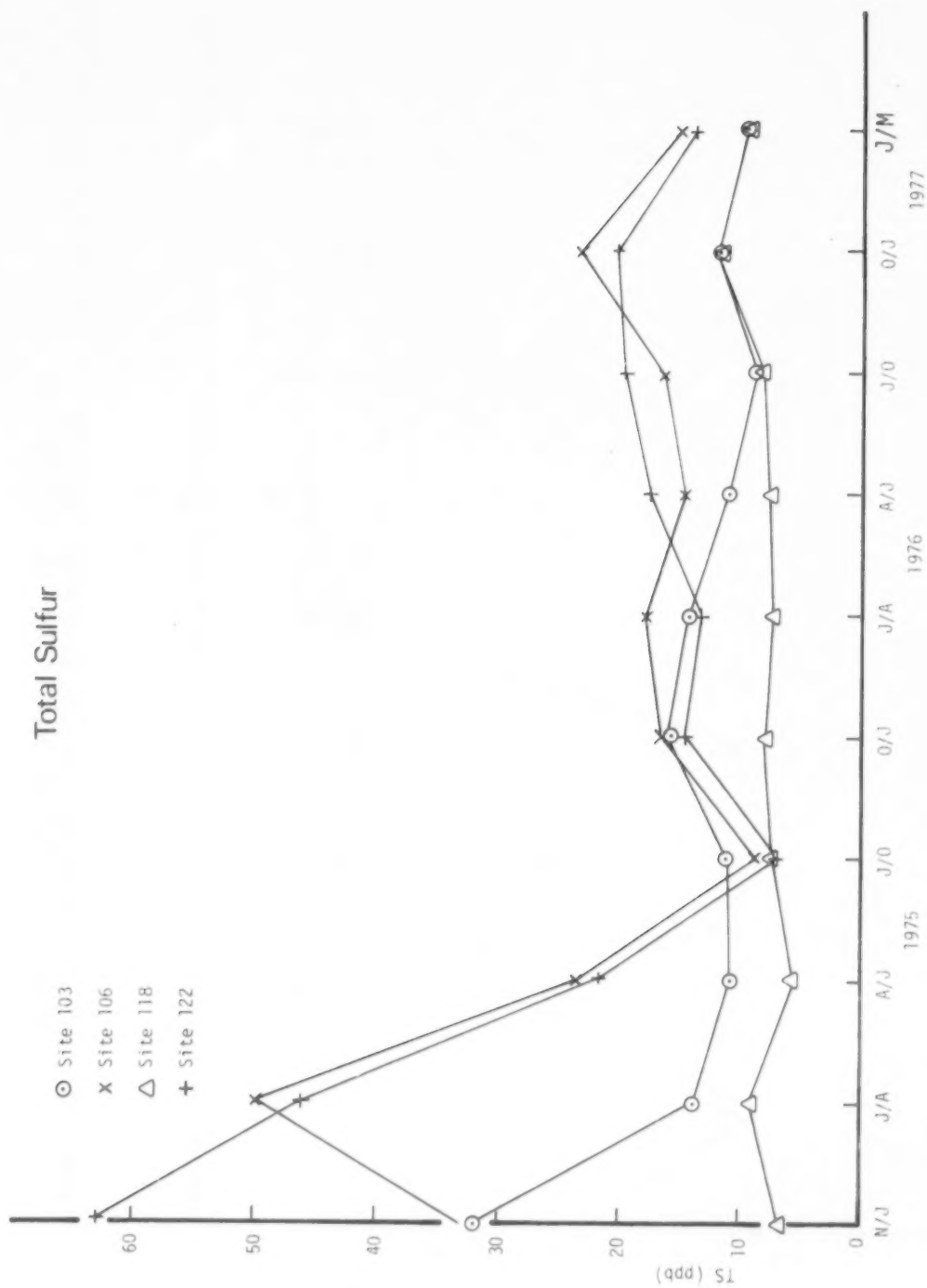


FIGURE 23e. THREE-MONTH AVERAGES OF TOTAL SULFUR (ppb) FOR THE TIME BETWEEN NOV. 10, 1974 AND MARCH 31, 1977 AT SITES #103, 106, 118 AND 122.

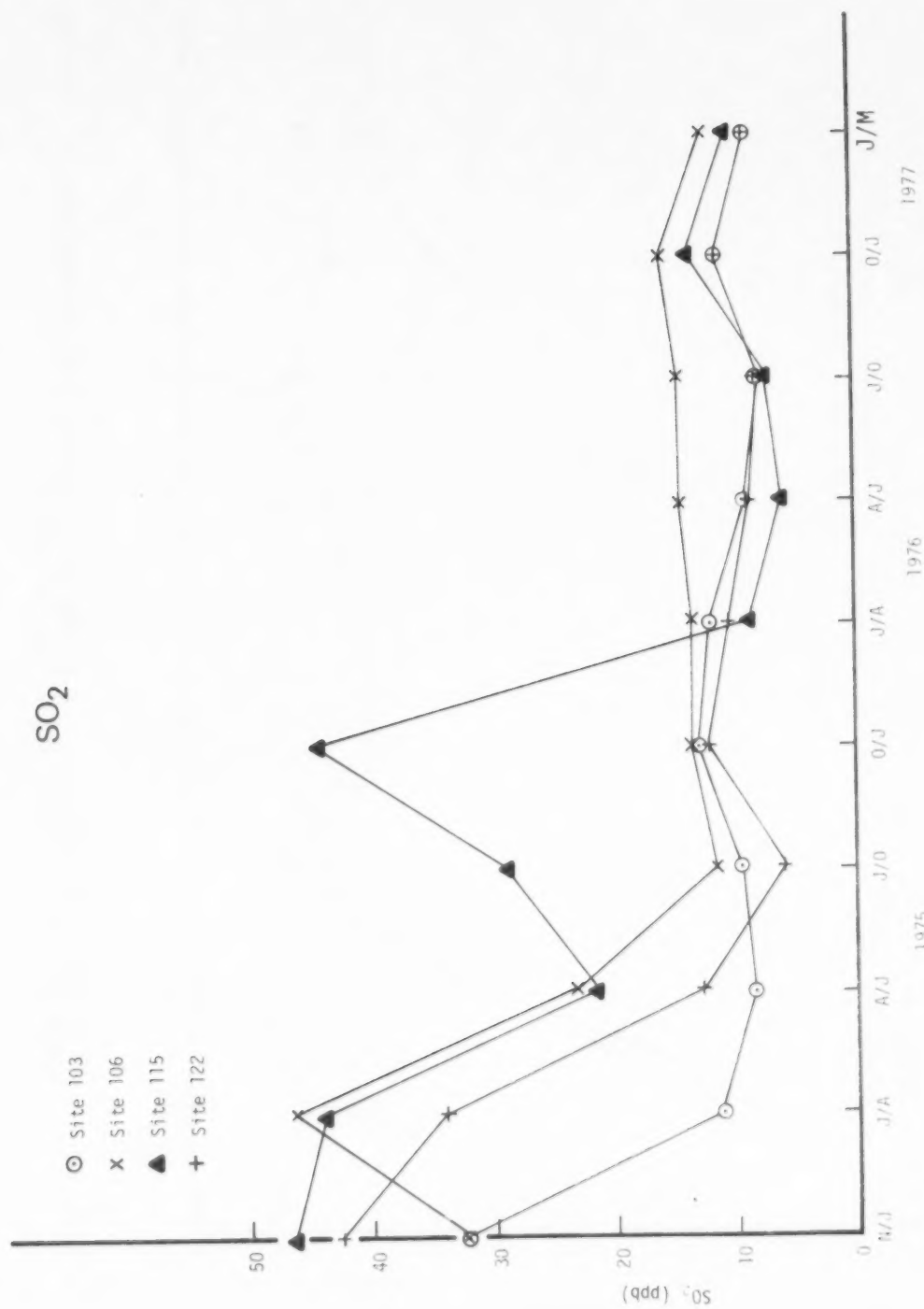


FIGURE 23f. THREE-MONTH AVERAGES OF SULFUR DIOXIDE (ppb) FOR THE TIME BETWEEN NOV. 10, 1974 AND MARCH 31, 1977 AT SITES #103, 106, 115 AND 122.

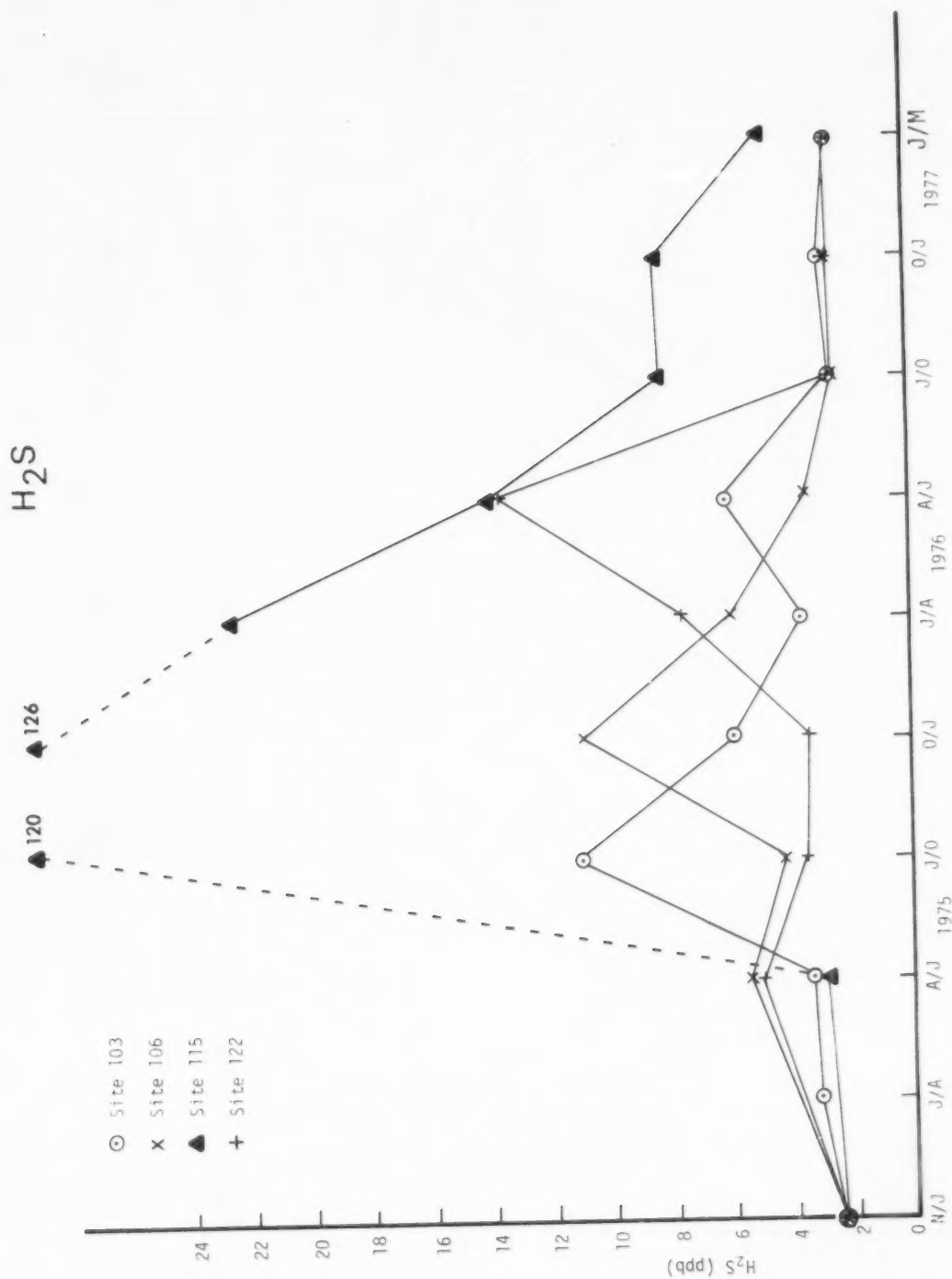


FIGURE 23g. THREE-MONTH AVERAGES OF HYDROGEN SULFIDE (ppb) FOR THE TIME BETWEEN NOV. 10, 1974 AND MARCH 31, 1977 AT SITES #103, 106, 115 AND 122.

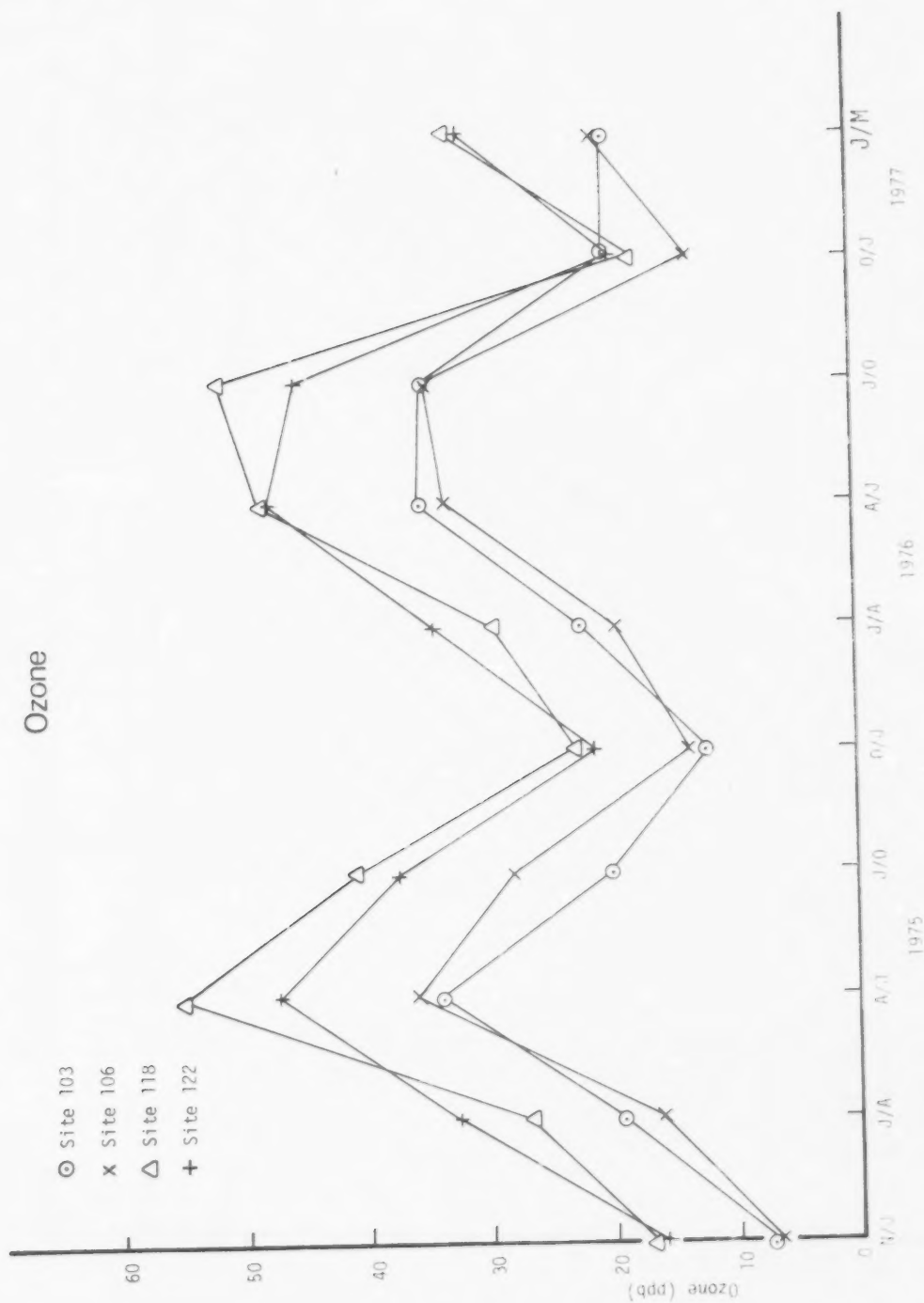


FIGURE 23h. THREE-MONTH AVERAGES OF OZONE (ppb) FOR THE TIME BETWEEN NOV. 10, 1974 AND MARCH 31, 1977 AT SITES #103, 106, 118 AND 122.

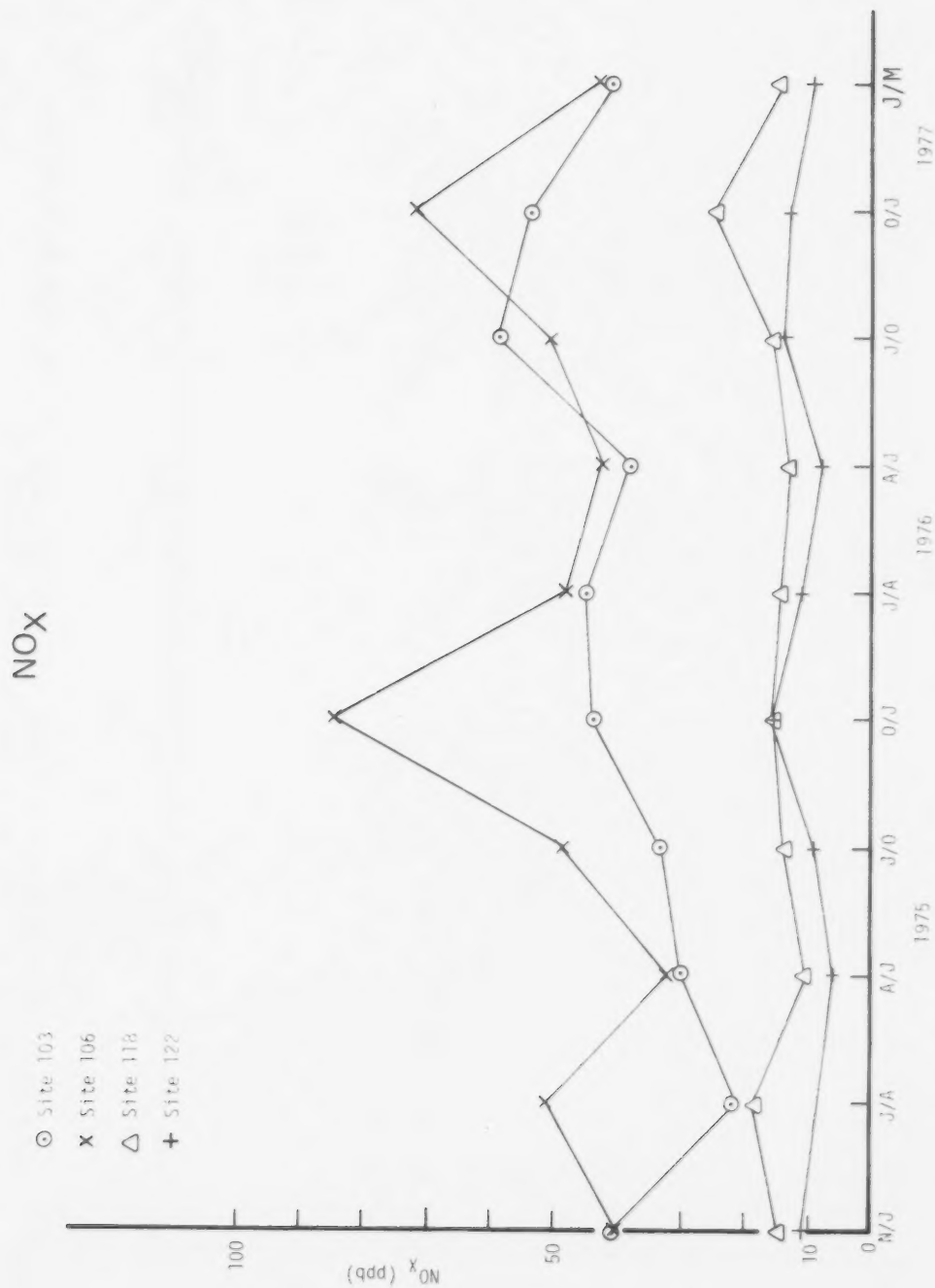


FIGURE 23i. THREE- MONTH AVERAGES OF OXIDES OF NITROGEN (ppb) FOR THE TIME BETWEEN NOV. 10, 1974 AND MARCH 31, 1977 AT SITES #103, 106, 118 AND 122.

THC

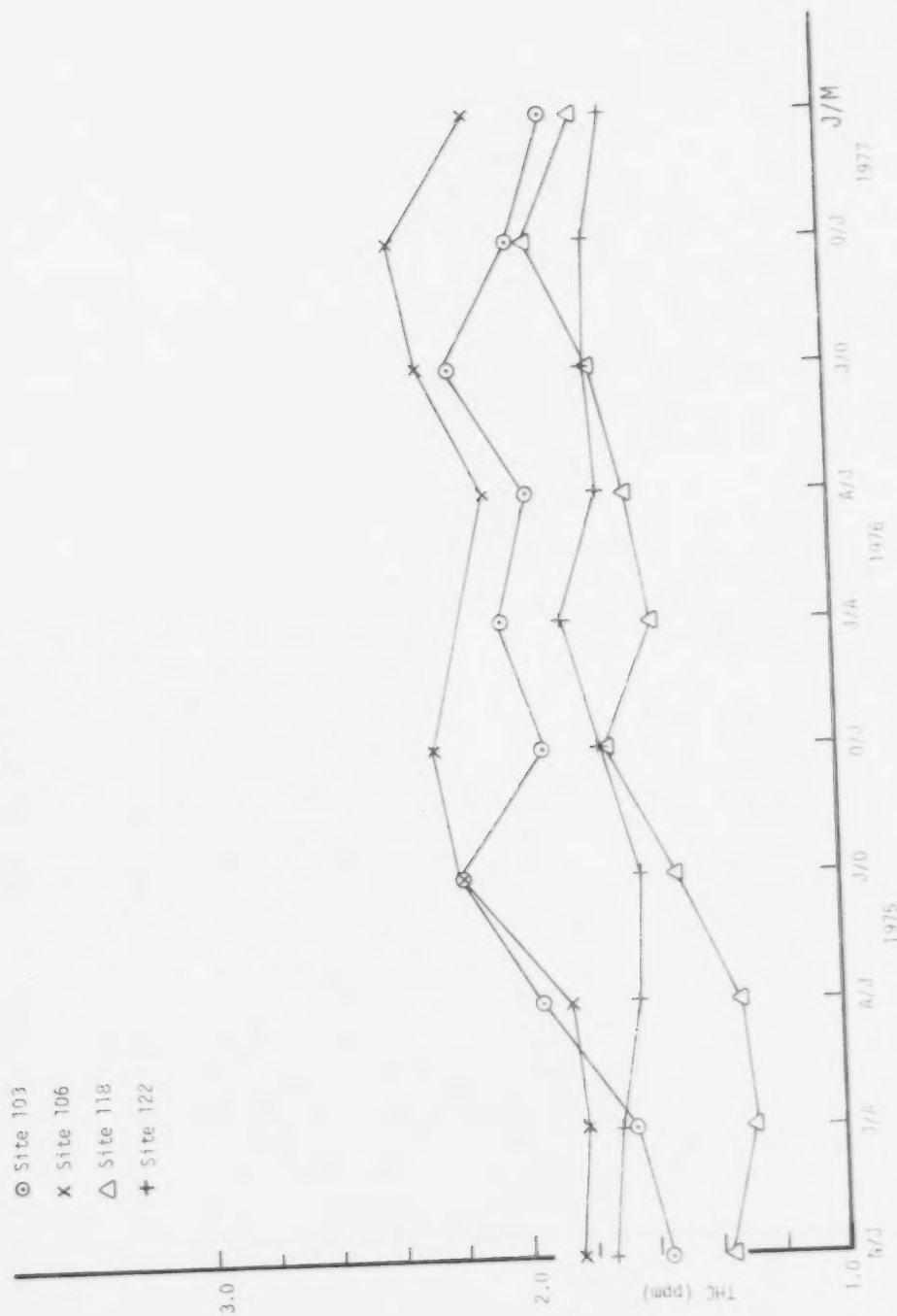


FIGURE 23j. THREE-MONTH AVERAGES OF TOTAL HYDROCARBON (ppm) FOR THE TIME BETWEEN NOV. 10, 1974 AND MARCH 31, 1977 AT SITES #103, 106, 118 AND 122.

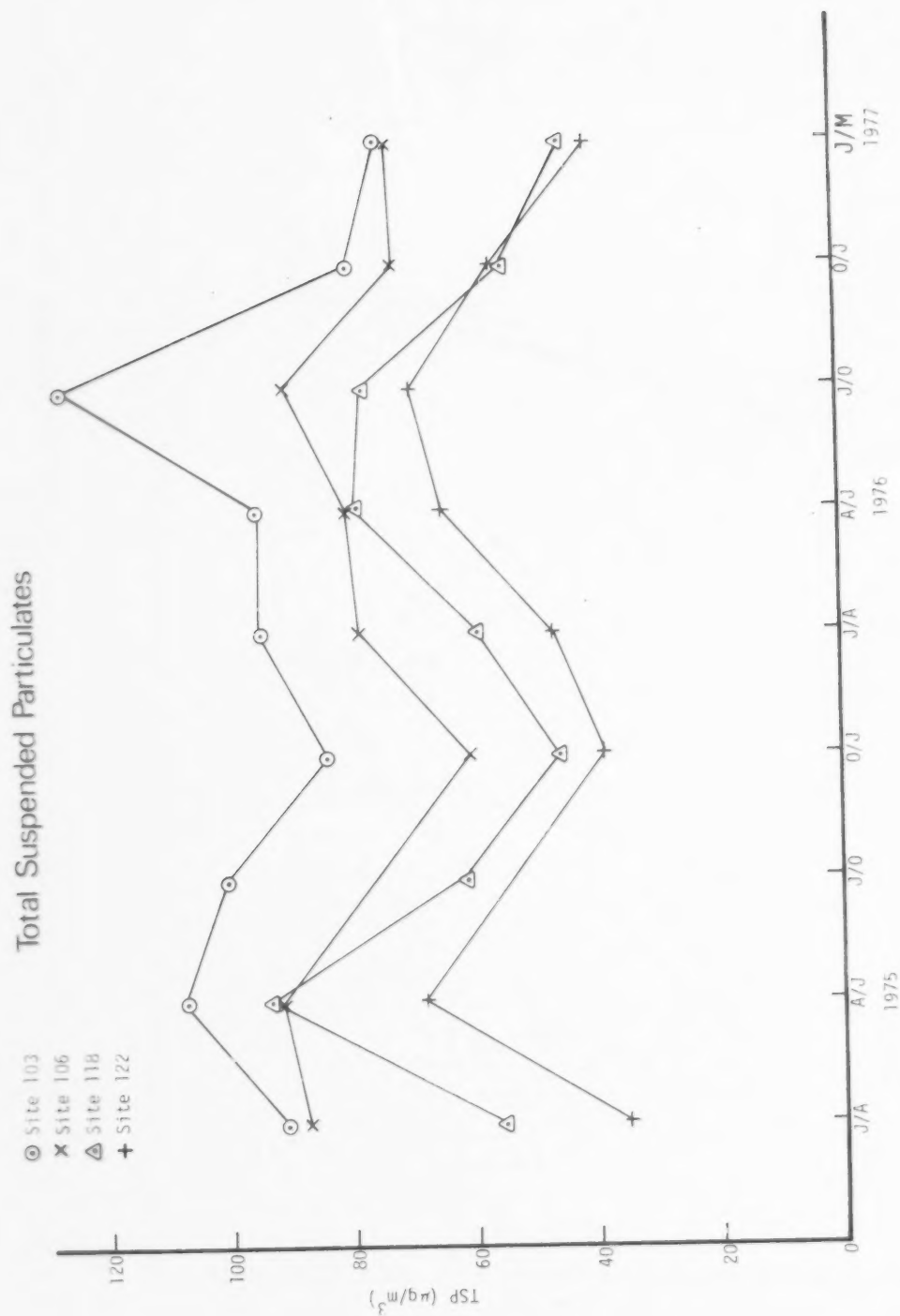


FIGURE 24a. THREE-MONTH AVERAGES OF TOTAL SUSPENDED PARTICULATES ($\mu\text{g}/\text{m}^3$) FOR THE TIME BETWEEN NOV. 10, 1974 AND MARCH 31, 1977 AT SITES #103, 106, 118 AND 122.

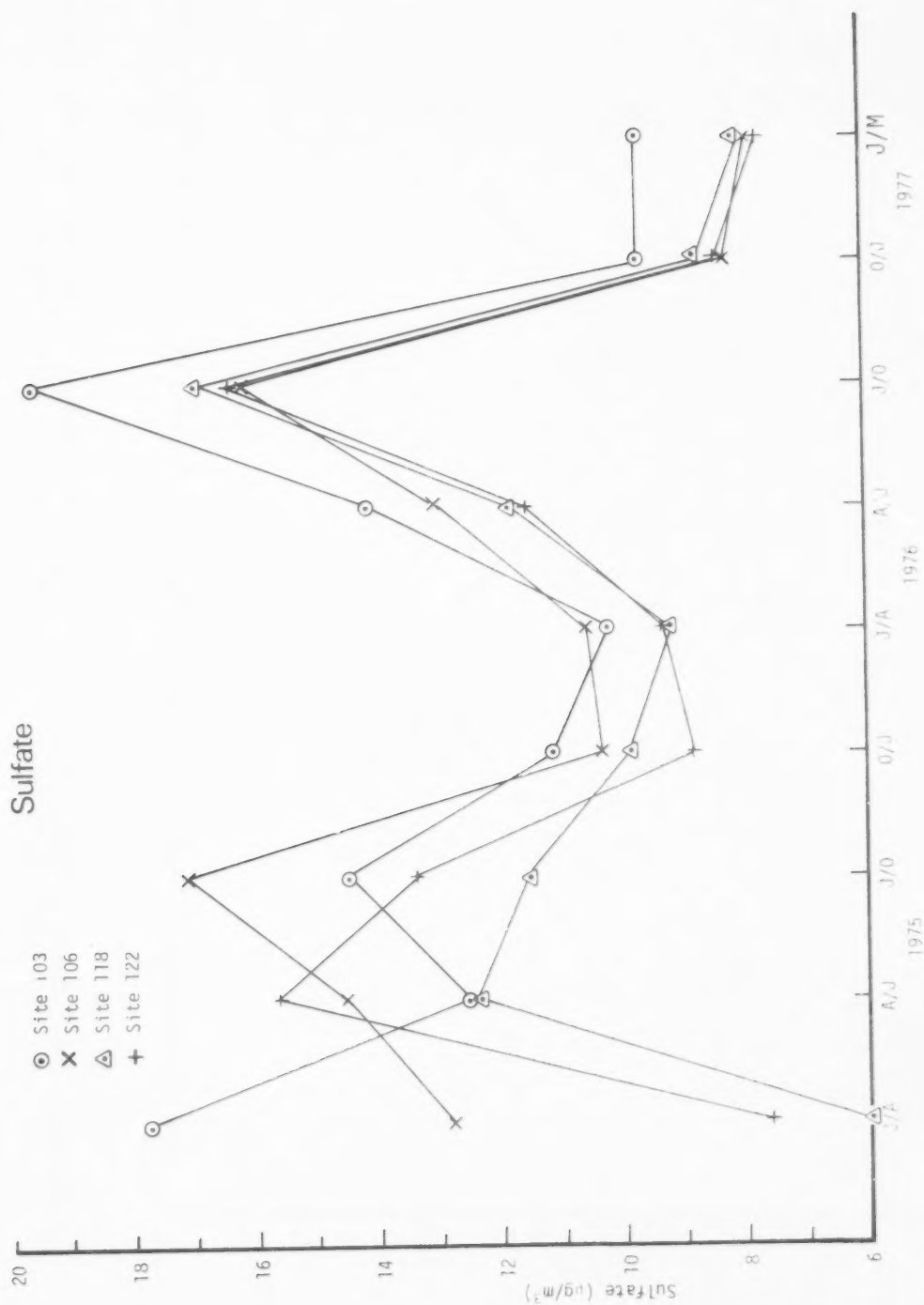


FIGURE 24b. THREE-MONTH AVERAGES OF SULFATE ($\mu\text{g}/\text{m}^3$) FOR THE TIME BETWEEN NOV. 10, 1974 AND MARCH 31, 1977 AT SITES #103, 106, 118 AND 122.

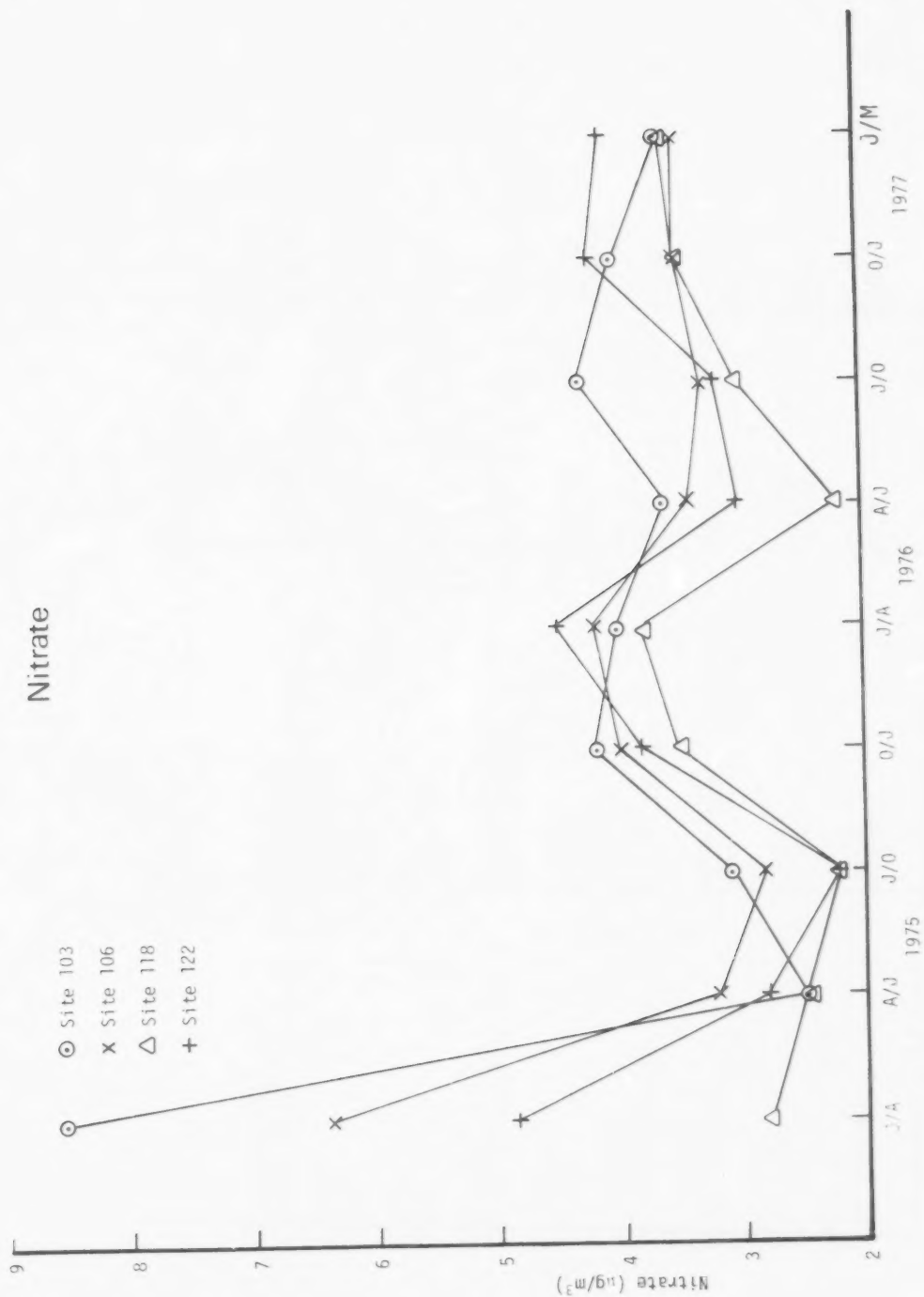


FIGURE 24c. THREE-MONTH AVERAGES OF NITRATE ($\mu\text{g}/\text{m}^3$) FOR THE TIME BETWEEN NOV. 10, 1974 AND MARCH 31, 1977 AT SITES #103, 106, 118 AND 122.

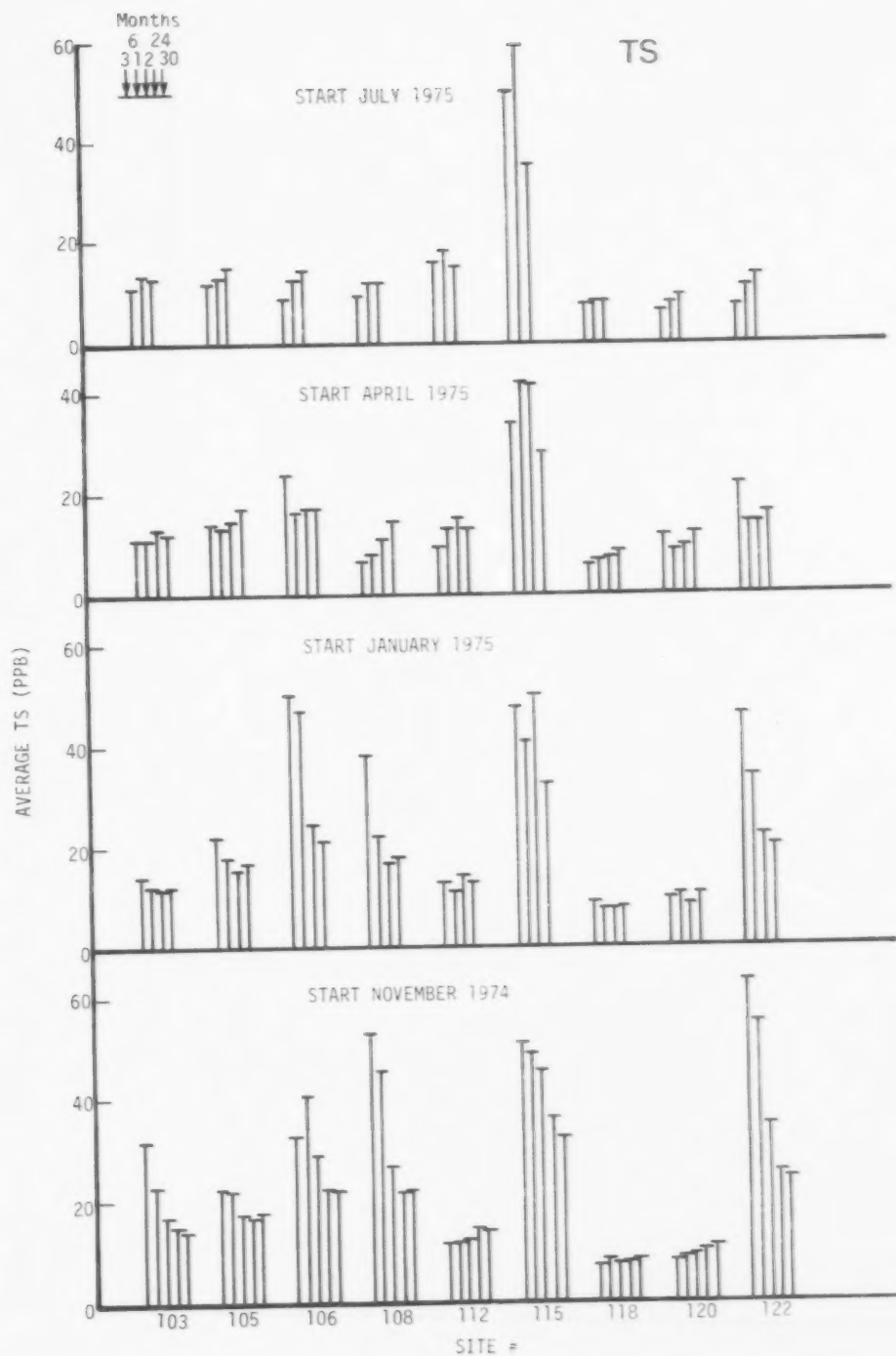


FIGURE 25a. AVERAGES OF TOTAL SULFUR (ppb) FOR DIFFERENT EXPOSURE LENGTHS AND START OF EXPOSURE.

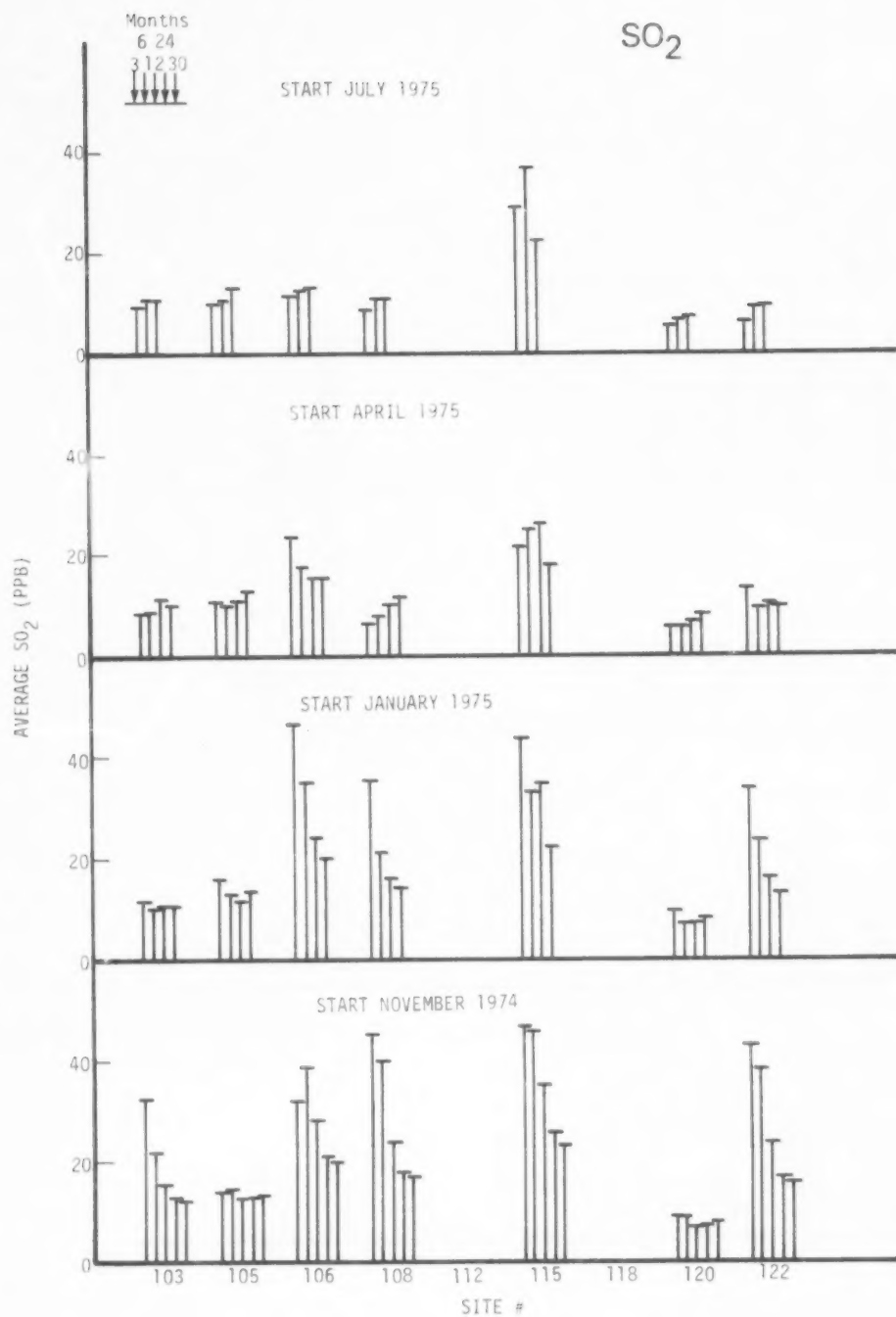


FIGURE 25b. AVERAGES OF SULFUR DIOXIDE (ppb) FOR DIFFERENT EXPOSURE LENGTHS AND START OF EXPOSURE.

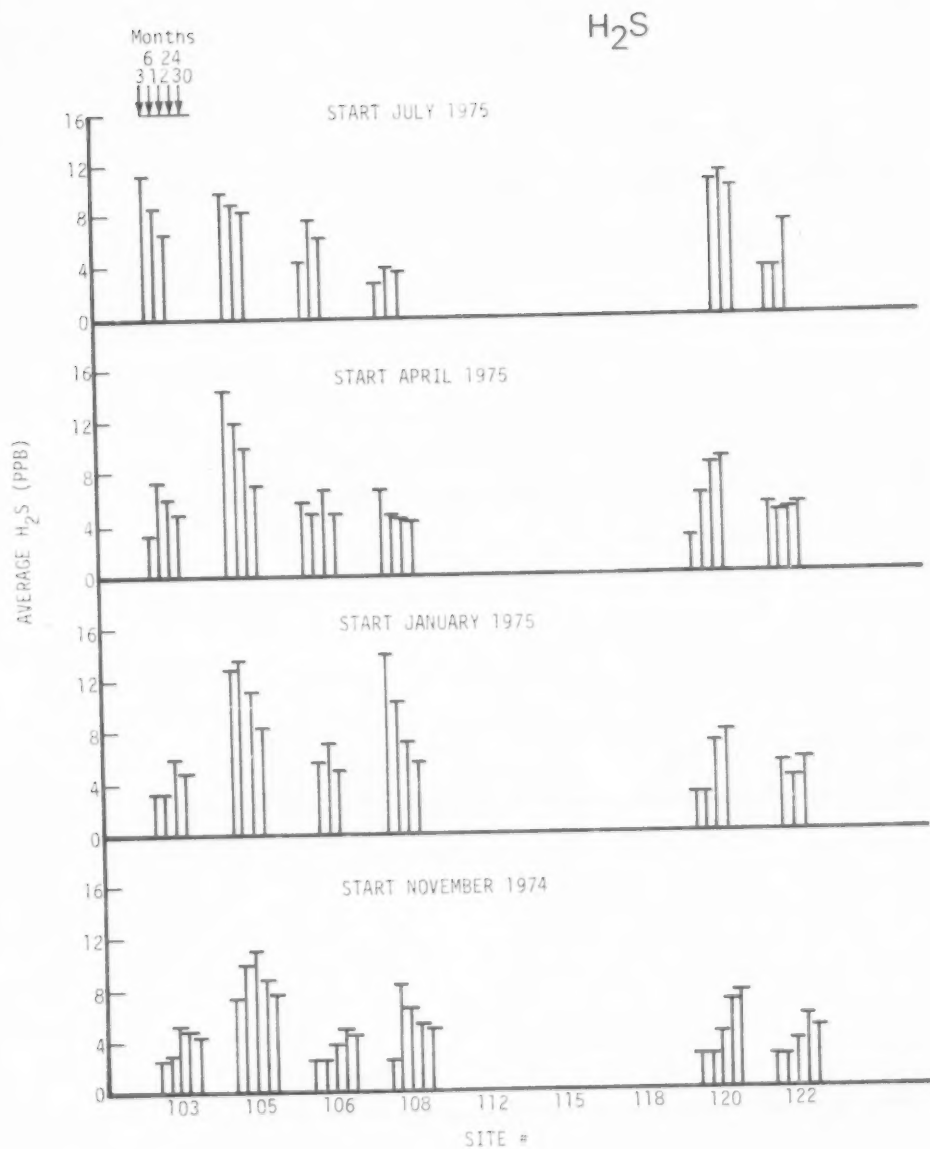


FIGURE 25c. AVERAGES OF HYDROGEN SULFIDE (ppb) FOR DIFFERENT EXPOSURE LENGTHS AND START OF EXPOSURE (DATA FOR SITE #115 NOT SHOWN WERE OFF SCALE, SEE TABLE 20, III.)

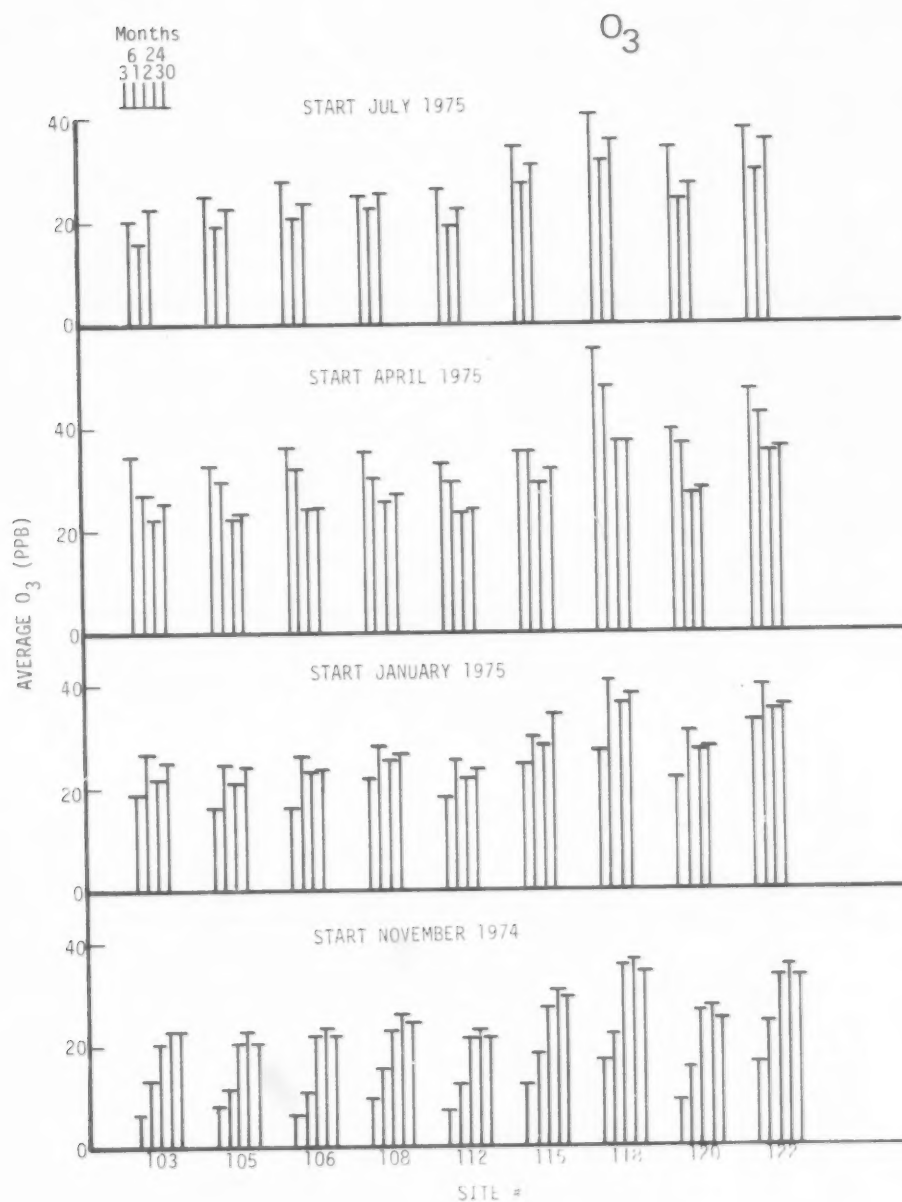


FIGURE 25d. AVERAGES OF OZONE (ppb) FOR DIFFERENT EXPOSURE LENGTHS AND START OF EXPOSURE

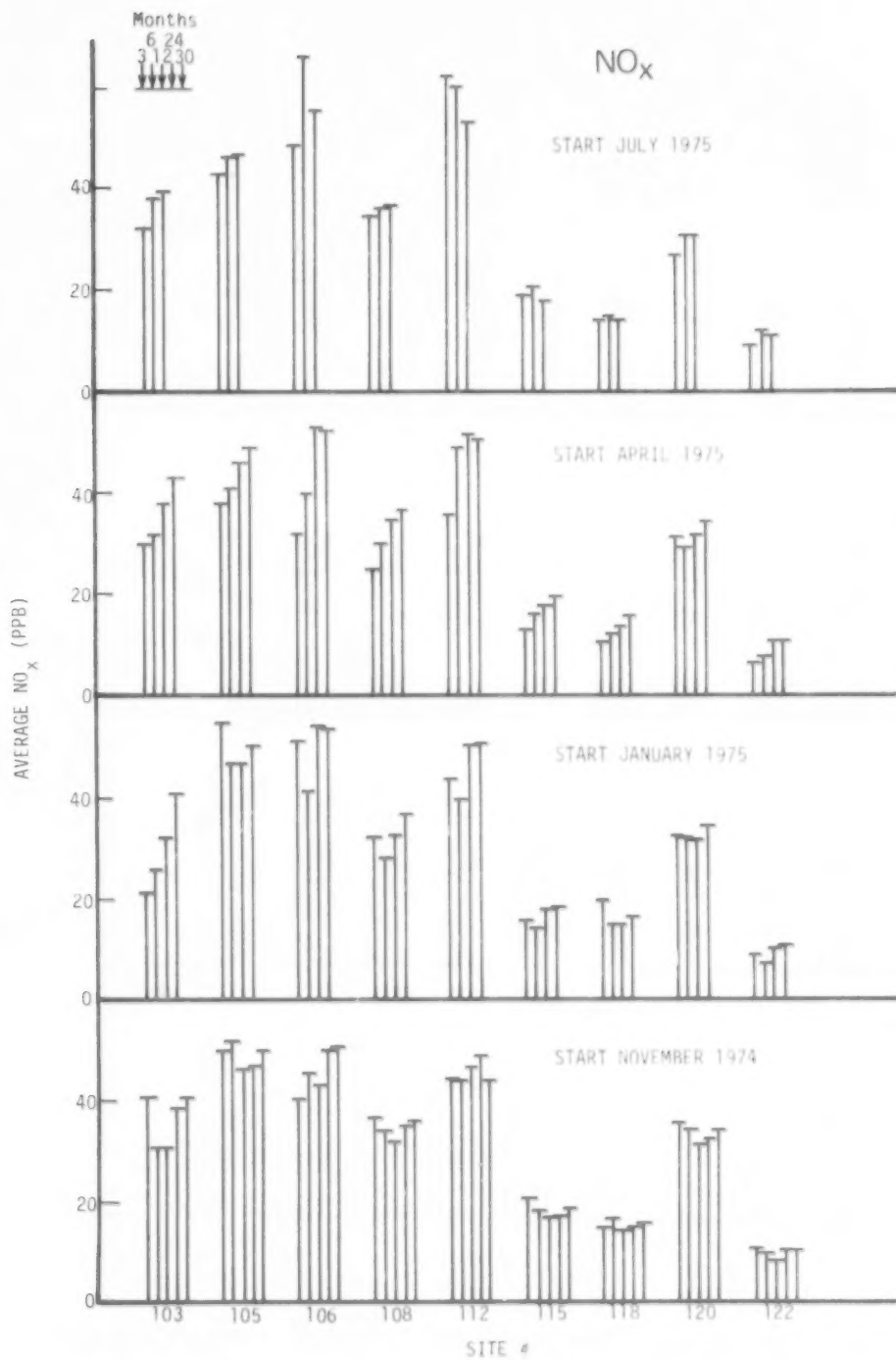


FIGURE 25e. AVERAGES OF OXIDES OF NITROGEN (ppb) FOR DIFFERENT EXPOSURE LENGTHS AND START OF EXPOSURE.

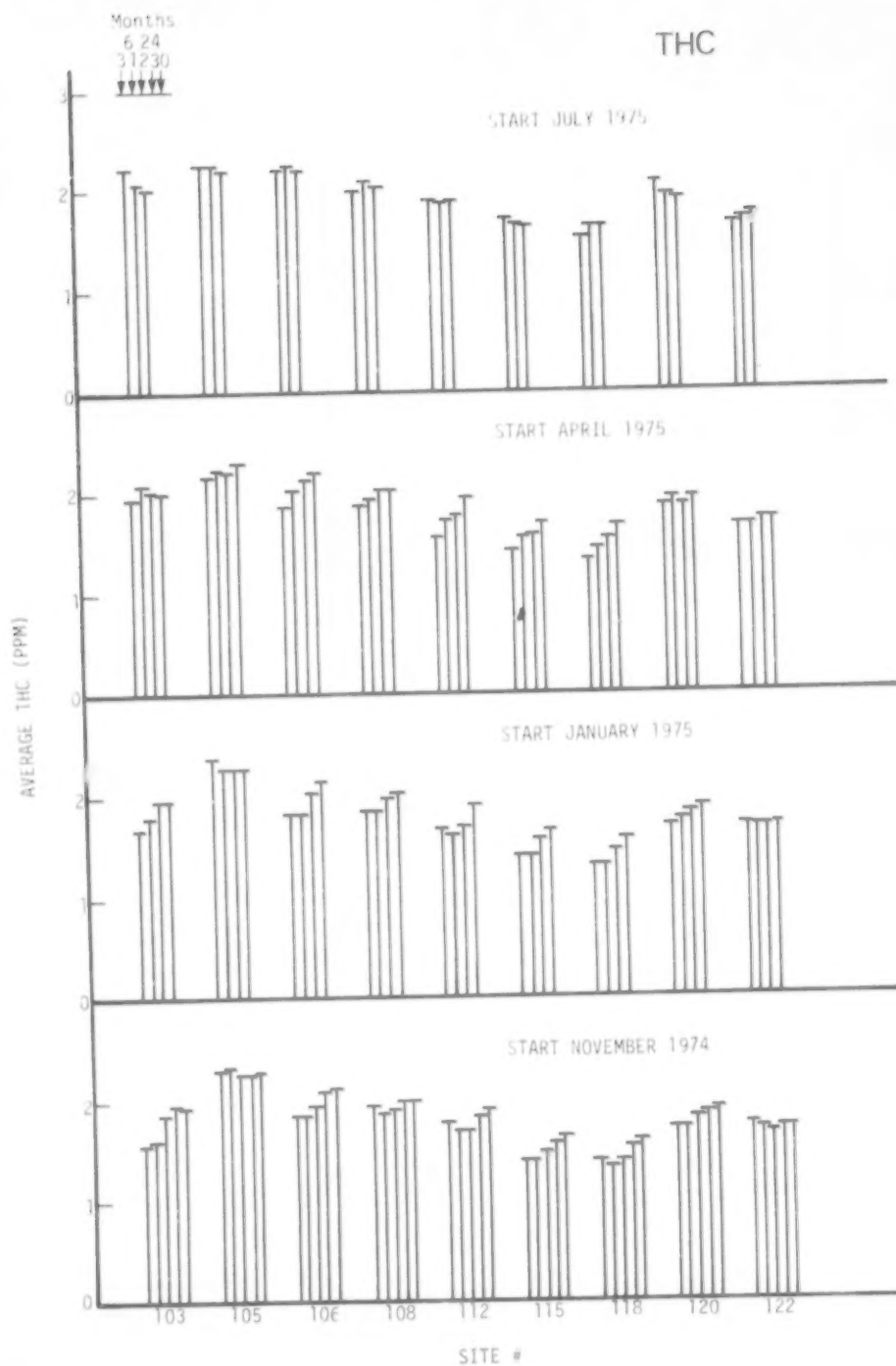


FIGURE 25f. AVERAGES OF TOTAL HYDROCARBON (ppm) FOR DIFFERENT EXPOSURE LENGTHS AND START OF EXPOSURE.

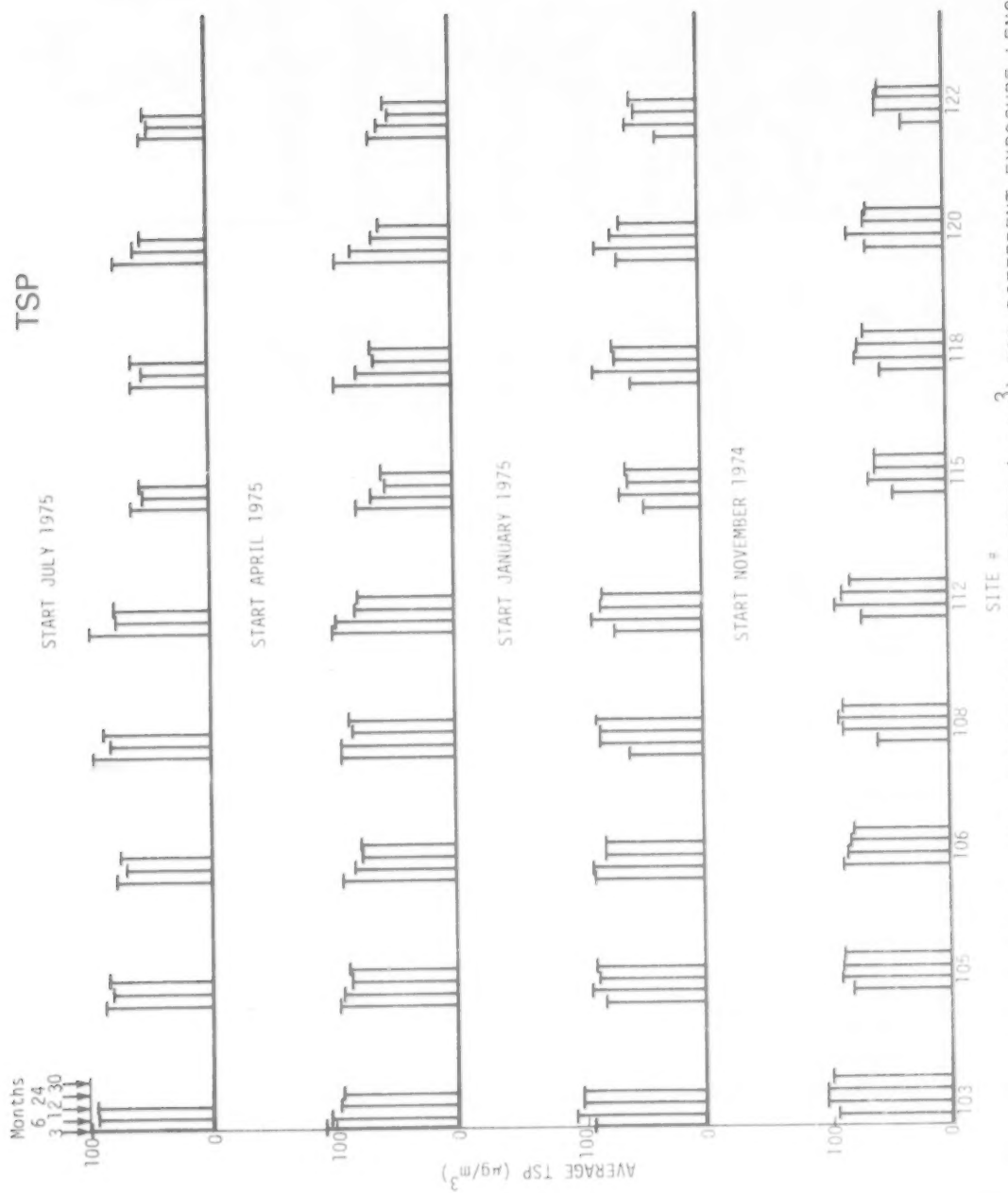


FIGURE 26a AVERAGES OF TOTAL SUSPENDED PARTICULATES ($\mu\text{g}/\text{m}^3$) FOR DIFFERENT EXPOSURE LENGTHS AND START OF EXPOSURE.

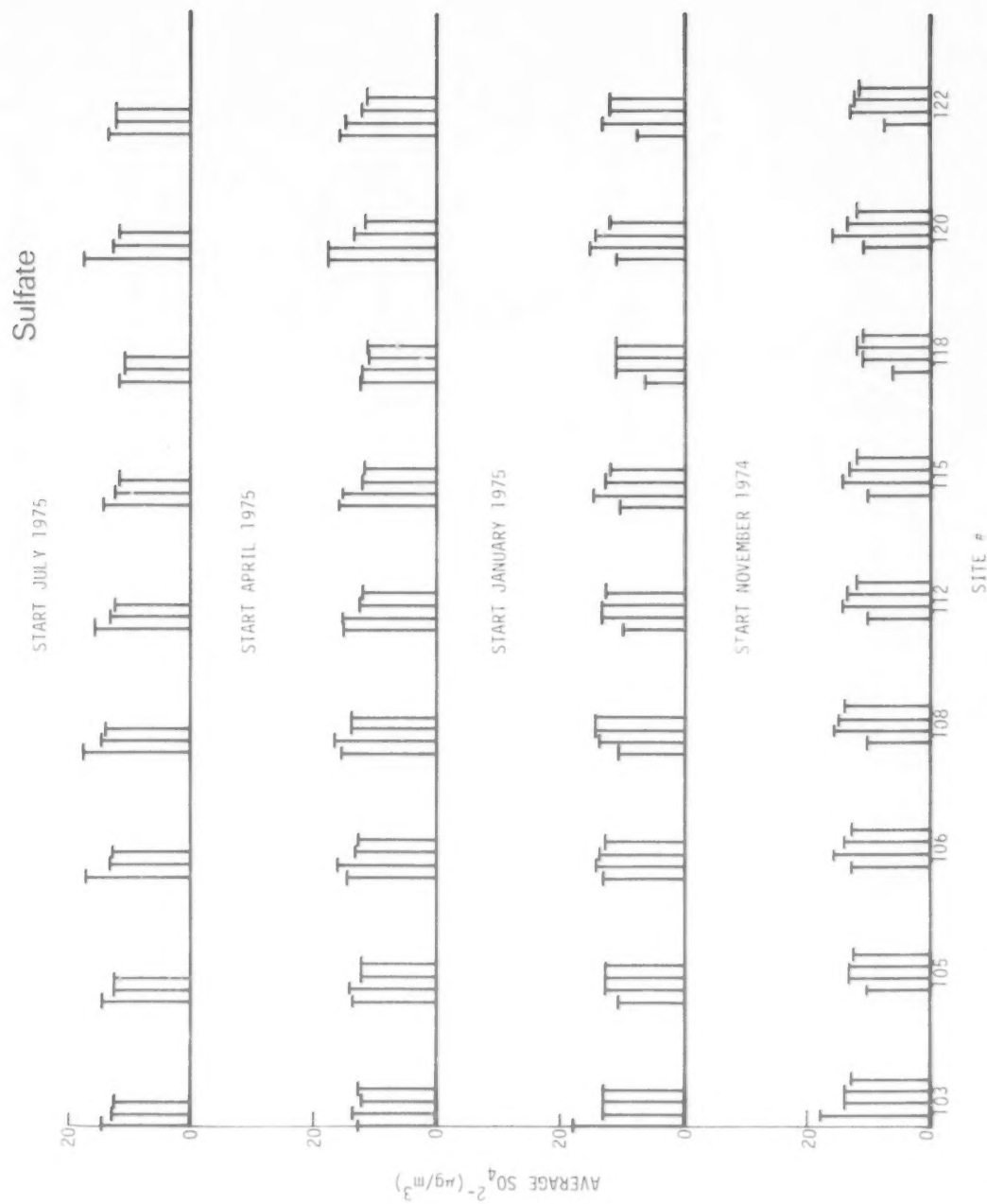


FIGURE 26b. AVERAGES OF SULFATE ($\mu\text{g}/\text{m}^3$) FOR DIFFERENT EXPOSURE LENGTHS AND START OF EXPOSURE.

Nitrate

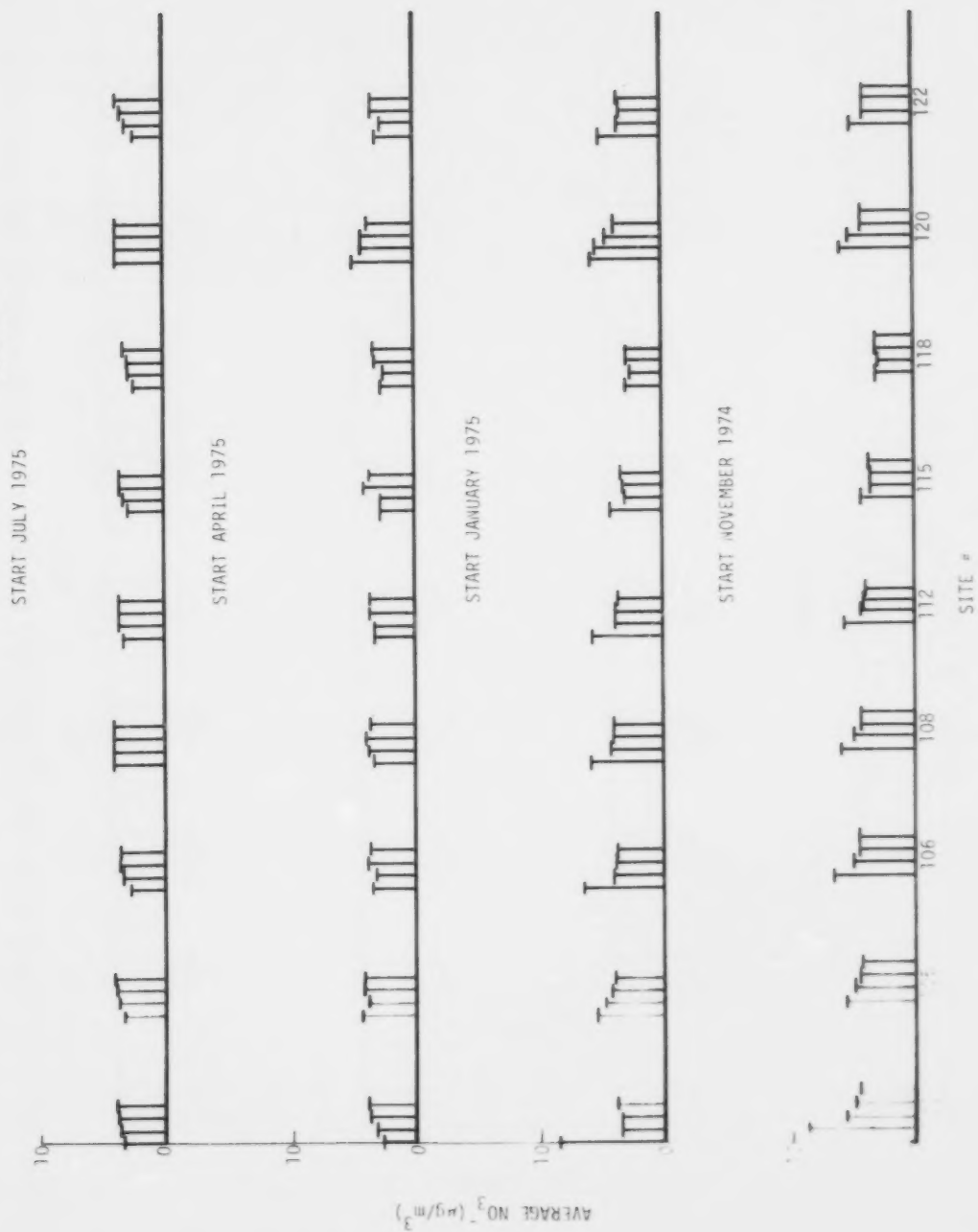


FIGURE 16. AVERAGES OF NITRATE ($\mu\text{g}/\text{m}^3$) FOR DIFFERENT EXPOSURE LENGTHS AND START OF EXPOSURE.

Table 1. Materials, Preparation, Exposure Conditions and Assessment of Corrosion Damage

<u>Material</u>	<u>Exposure Condition</u>	<u>Sample Preparation</u>	<u>Assessment</u>
<u>Galvanized Steel</u> (4" x 6" x 0.036")	30° from horizontal facing south	Degrease, clean, weigh	Gravimetric
<u>Weathering Steel</u> (Corten A) (4" x 6" x 0.036")	30° from horizontal facing south	Degrease, descale, weigh	Gravimetric
<u>A1 7079-T651</u> (tension specimen in short transverse direction, 15 and 25 Ksi stress level)	30° from horizontal facing south	Degrease, stress	Time-to-failure
<u>A1 2014-T651</u> (tension specimen in short transverse direction, 45 and 25 Ksi stress level)	30° from horizontal facing south	Degrease, stress	Time-to-failure
<u>House Paint</u> on stainless steel (4" x 6" x 0.036", type 3 with 2B finish)	Vertical facing north and south	Degrease, clean, apply paint, condition, weigh	Gravimetric, loss of reflectance
a. oil base, 2.5 mil.			
b. latex, 1.5 mil			
<u>White Cherokee Marble</u> (4" x 6" x 3/8")	30° from horizontal facing south	Clean, condition, weigh	Visual, gravimetric
<u>Silver</u> (6" diameter plated discs)	Open to ambient air but protected from direct environmental factors	Degrease	Visual, loss of reflectance, electrochemical
<u>Textile-Nylon</u> (15 denier nylon filament)	Horizontal, no protection	Stress and mount on plastic slide	Visual inspection for defects

Table 2. Air Quality Data Used for This Project

<u>Parameter</u>	<u>Code</u>
Wind speed (m/sec)	WS
Wind direction (degrees)	WD
Temperature ($^{\circ}\text{C}$)	TEMP
Ozone concentration (ppb)	OZONE
Total hydrocarbon concentration (ppm)	THC
NO_x concentration (ppb)	NOX
Total sulfur concentration (ppb)	TS
H_2S concentration (ppb)	H2S
SO_2 concentration (ppb)	S02
Relative humidity (%)	RH
Sulfate ($\mu\text{g}/\text{m}^3$)	S04
Nitrate ($\mu\text{g}/\text{m}^3$)	NO3
Total Suspended Particulates ($\mu\text{g}/\text{m}^3$)	TSP

Table 3. Weight Loss of Galvanized Steel (mg)

1st Set, Start 10-15-74

<u>Site</u>	<u>3 Months</u>	<u>6 Months</u>	<u>12 Months</u>	<u>24 Months</u>	<u>30 Months</u>
103	82.3 $\pm$ 0.1	159.2 $\pm$ 0.1	264.9 $\pm$ 0.5	431.7 $\pm$ 4.9	510.0 $\pm$ 3.2
105	63.7 $\pm$ 0.2	144.5 $\pm$ 5.8	273.4 $\pm$ 0.6	464.0 $\pm$ 2.6	558.9 $\pm$ 4.1
106	63.3 $\pm$ 1.4	123.2 $\pm$ 0.9	234.3 $\pm$ 7.2	406.8 $\pm$ 12.2	499.9 $\pm$ 0.4
108	79.6 $\pm$ 1.3	151.0 $\pm$ 0.1	266.6 $\pm$ 0.2	497.2 $\pm$ 1.2	619.0 $\pm$ 5.4
112	58.6 $\pm$ 5.2	123.5 $\pm$ 1.8	217.2 $\pm$ 3.8	412.7 $\pm$ 2.3	489.9 $\pm$ 6.5
115	70.2 $\pm$ 3.1	128.4 $\pm$ 1.6	242.1 $\pm$ 2.1	425.8 $\pm$ 0.4	526.3 $\pm$ 6.6
118	54.7 $\pm$ 0.5	120.4 $\pm$ 5.6	212.9 $\pm$ 8.0	379.7 $\pm$ 9.8	481.1 $\pm$ 2.4
120	62.1 $\pm$ 7.9	111.9 $\pm$ 1.6	192.8 $\pm$ 0.7	387.6 $\pm$ 11.2	461.5 $\pm$ 6.3
122	88.6 $\pm$ 0.7	133.2 $\pm$ 2.3	229.3 $\pm$ 2.2	471.6 $\pm$ 0.2	590.7 $\pm$ 8.3

2nd Set, Start 1-15-75

<u>Site</u>	<u>3 Months</u>	<u>6 Months</u>	<u>12 Months</u>	<u>24 Months</u>
103	85.4 $\pm$ 3.6	130.5 $\pm$ 11.9	244.6 $\pm$ 6.1	395.3 $\pm$ 13.1
105	85.9 $\pm$ 5.8	139.7 $\pm$ 9.4	230.3 $\pm$ 3.3	439.1 $\pm$ 0.8
106	67.8 $\pm$ 3.2	111.6 $\pm$ 2.1	192.0 $\pm$ 7.4	351.7 $\pm$ 0.5
108	64.1 $\pm$ 1.7	124.6 $\pm$ 3.0	220.8 $\pm$ 3.8	421.5 $\pm$ 5.6
112	65.5 $\pm$ 0.3	111.9 $\pm$ 0.6	194.5 $\pm$ 5.0	356.9 $\pm$ 0.1
115	62.2 $\pm$ 2.7	111.1 $\pm$ 3.7	208.6 $\pm$ 12.6	363.6 $\pm$ 2.2
118	67.3 $\pm$ 4.2	106.7 $\pm$ 2.5	186.7 $\pm$ 2.6	364.0 $\pm$ 1.5
120	58.8 $\pm$ 2.8	98.8 $\pm$ 0.4	198.8 $\pm$ 0.1	342.6 $\pm$ 2.1
122	50.5 $\pm$ 0.1	104.3 $\pm$ 1.0	204.0 $\pm$ 7.5	410.4 $\pm$ 0.5

Table 3 (Continued)

3rd Set, Start 4-15-75

<u>Site</u>	<u>3 Months</u>	<u>6 Months</u>	<u>12 Months</u>	<u>15 Months</u>
103	59.7 $\pm$ 1.5	93.6 $\pm$ 1.0	180.3 $\pm$ 0.8	216.8 $\pm$ 2.8
105	45.0 $\pm$ 1.6	77.2 $\pm$ 0.7	146.2 $\pm$ 1.2	197.5 $\pm$ 2.9
106	39.5 $\pm$ 2.7	71.5 $\pm$ 1.7	128.5 $\pm$ 0.1	168.7 $\pm$ 3.6
108	50.5 $\pm$ 0.1	86.6 $\pm$ 1.4	173.0 $\pm$ 1.4	225.4 $\pm$ 2.4
112	36.6 $\pm$ 0.2	72.5 $\pm$ 3.4	129.7 $\pm$ 2.7	170.7 $\pm$ 1.3
115	54.5 $\pm$ 1.7	77.7 $\pm$ 2.0	155.4 $\pm$ 1.0	199.1 $\pm$ 1.6
118	41.4 $\pm$ 0.6	71.0 $\pm$ 0.5	143.0 $\pm$ 8.0	196.2 $\pm$ 0.0
120	34.5 $\pm$ 1.1	59.5 $\pm$ 0.6	118.1 $\pm$ 1.8	165.4 $\pm$ 1.2
122	50.3 $\pm$ 1.7	88.6 $\pm$ 6.4	177.3 $\pm$ 14.7	242.8 $\pm$ 16.8

4th Set, Start 7-9-75

<u>Site</u>	<u>3 Months</u>	<u>6 Months</u>	<u>12 Months</u>	<u>21 Months</u>
103	49.6 $\pm$ 1.3	101.6 $\pm$ 2.7	192.6 $\pm$ 5.8	289.7 $\pm$ 1.1
105	52.4 $\pm$ 0.3	98.5 $\pm$ 5.0	176.5 $\pm$ 2.7	300.0 $\pm$ 3.9
106	39.2 $\pm$ 1.4	73.0 $\pm$ 2.6	143.4 $\pm$ 1.8	264.7 $\pm$ 0.7
108	59.2 $\pm$ 0.7	109.4 $\pm$ 4.9	188.9 $\pm$ 12.8	328.2 $\pm$ 0.5
112	37.5 $\pm$ 2.2	76.9 $\pm$ 1.6	155.8 $\pm$ 12.1	254.3 $\pm$ 3.3
115	48.0 $\pm$ 4.9	105.1 $\pm$ 1.6	193.6 $\pm$ 2.9	287.0 $\pm$ 0.4
118	45.1 $\pm$ 3.0	100.9 $\pm$ 3.0	195.6 $\pm$ 21.6	289.9 $\pm$ 13.0
120	36.2 $\pm$ 1.2	76.0 $\pm$ 1.2	149.9 $\pm$ 5.5	263.6 $\pm$ 4.6
122	60.9 $\pm$ 4.0	125.9 $\pm$ 2.3	234.4 $\pm$ 11.2	300.1 $\pm$ 14.8

Table 4. Integral Corrosion Rates V_i ($\mu\text{g}/\text{cm}^2$ month) for Galvanized Steel (Area = 310 cm^2)

<u>1st Set, Start 10-15-74</u>					
<u>Site</u>	<u>3 Mo.</u>	<u>6 Mo.</u>	<u>12 Mo.</u>	<u>24 Mo.</u>	<u>30 Mo.</u>
103	89.4	85.5	71.3	58.1	55.8
105	68.4	77.7	73.2	62.3	60.0
106	68.1	66.1	62.1	54.8	53.9
108	85.5	81.3	71.6	66.8	66.5
112	62.9	66.5	58.4	55.5	52.6
115	75.5	69.0	65.2	57.1	56.5
118	58.7	64.8	57.1	51.0	51.6
120	66.8	60.3	51.9	52.3	49.7
122	95.2	71.6	61.6	63.5	63.5

Note: $100 \mu\text{g}/\text{cm}^2$ month $\approx 1.68 \mu\text{m}/\text{yr}$

<u>2nd Set, Start 1-15-75</u>				
<u>Site</u>	<u>3 Mo.</u>	<u>6 Mo.</u>	<u>12 Mo.</u>	<u>24 Mo.</u>
103	91.9	70.3	65.8	53.2
105	92.2	75.2	61.9	59.0
106	72.9	60.0	51.6	47.4
108	69.0	67.1	59.4	56.8
112	70.3	60.3	52.3	48.1
115	66.8	59.7	55.2	48.7
118	72.3	57.4	50.3	49.0
120	63.2	53.2	53.5	46.1
122	54.2	56.1	54.8	55.2

Table 4 (Continued)

3rd Set, Start 4-15-75

<u>Site</u>	<u>3 Mo.</u>	<u>6 Mo.</u>	<u>12 Mo.</u>	<u>15 Mo.</u>
103	64.2	50.3	48.4	46.8
105	48.4	41.6	39.4	42.6
106	42.6	38.4	34.5	36.1
108	54.2	46.5	46.5	48.4
112	39.4	39.0	34.8	45.2
115	58.7	41.9	41.9	42.6
118	44.5	38.1	38.4	42.3
120	37.1	31.9	31.6	35.5
122	54.2	47.7	47.7	52.3

4th Set, Start 7-9-75

<u>Site</u>	<u>3 Mo.</u>	<u>6 Mo.</u>	<u>12 Mo.</u>	<u>21 Mo.</u>
103	53.2	54.5	51.9	44.5
105	56.5	52.9	47.4	46.1
106	42.3	39.4	38.7	40.6
108	63.5	58.7	50.6	50.3
112	40.3	41.3	41.9	39.0
115	51.6	56.5	51.9	44.2
118	48.4	54.2	52.6	44.5
120	39.0	41.0	40.3	40.6
122	65.5	67.7	62.9	46.1

Table 5. Corrosion Parameters n and k for Galvanized Steel
(k in mg/cm^2 month)

Site	First Set		Second Set		Third Set		Fourth Set	
	n	k	n	k	n	k	n	k
103	0.26	0.135	0.23	0.12	0.17	0.076	0.15	0.071
105	0.13	0.097	0.21	0.11	0.07	0.050	0.10	0.063
106	0.13	0.094	0.22	0.083	0.13	0.050	0.03	0.043
108	0.11	0.097	0.10	0.077	0.08	0.072	0.11	0.060
112	0.13	0.083	0.17	0.081	0.05	0.042	0.00	0.040
115	0.13	0.087	0.14	0.079	0.00	0.042	0.12	0.066
118	0.17	0.087	0.17	0.087	0.01	0.076	0.03	0.083
120	0.12	0.076	0.14	0.074	0.03	0.037	0.02	0.039
122	0.07	0.079	0.00	0.055	0.00	0.053	0.02	0.069
Average	0.14	0.093	0.15	0.085	0.06	0.055	0.06	0.059
	+ 0.03	+0.012	+0.05	+0.014	+0.05	+0.013	+0.05	+0.012
	-	-	-	-	-	-	-	-

Note: $k = 0.1 \text{ mg}/\text{cm}^2$ month corresponds to $1.68 \text{ } \mu\text{m}/\text{year}$

Table 6. Weight loss of Weathering Steel (mg)

First Set - Start October 15, 1974

Site	3 Months	6 Months	12 Months	24 Months	30 Months
103	3814.5 + 270.2	5406.4 + 45.4	8351.6 + 185.0	9698.4 + 137.6	9946.6 + 61.3
105	2669.3 + 33.7	3828.9 + 21.7	5749.7 + 15.4	6638.2 + 32.1	6717.1 + 119.9
106	2612.4 + 29.4	3611.4 + 27.3	6330.4 + 76.9	7399.2 + 70.2	7633.0 + 87.7
108	3567.2 + 23.9	4787.7 + 9.2	8163.2 + 88.1	9969.6 + 5.8	10149.9 + 42.6
112	2504.1 + 35.8	3804.2 + 87.3	5963.9 + 85.1	7542.0 + 89.2	7520.2 + 127.1
115	3145.1 + 38.8	4569.5 + 66.6	7645.3 + 41.2	9951.2 + 58.1	10245.8 + 54.6
118	2567.8 + 39.8	3710.6 + 90.4	6693.3 + 169.4	8929.0 + 79.0	9185.1 + 40.0
120	2436.9 + 34.9	3475.8 + 16.1	5771.5 + 18.3	7079.3 + 14.2	7394.7 + 63.2
122	2918.8 + 23.6	4263.2 + 27.9	7820.0 + 68.3	10764.2 + 93.0	11071.0 + 254.7

Table 6. (continued)

Second Set - Start January 15, 1975

Site	3 Months	6 Months	12 Months	24 Months
103	3500.0 + 111.6	5624.9 + 199.4	7981.6 + 90.3	9119.9 + 9.7
105	2769.5 + 32.2	4014.6 + 18.8	5487.6 + 45.8	6253.2 + 30.8
106	2512.7 + 32.6	4294.2 + 20.4	6128.0 + 72.8	7026.4 + 8.4
108	2965.9 + 42.2	5498.7 + 70.1	7960.2 + 72.3	9274.6 + 111.8
112	2448.6 + 30.1	4130.4 + 10.2	5815.4 + 14.8	7197.4 + 398.0
115	2984.2 + 30.9	4819.8 + 68.9	7567.9 + 40.6	9126.6 + 16.6
118	2570.6 + 5.1	4324.3 + 43.8	6855.0 + 53.4	8277.8 + 111.1
120	2226.0 + 34.0	3694.6 + 31.5	5633.9 + 96.8	6738.6 + 27.0
122	2452.7 + 46.9	5238.3 + 33.8	7754.7 + 68.0	10123.1 + 163.5

Table 6. (continued)

Third Set - Start April 15, 1975

Site	3 Months	6 Months	12 Months	15 Months
103	3297.8 + 24.8	5558.9 + 88.5	6541.9 + 45.5	6977.8 + 122.1
105	2370.0 + 11.6	3740.5 + 22.9	4470.7 + 68.8	4887.7 + 58.6
106	2771.6 + 1.5	5102.9 + 67.3	6091.5 + 34.4	6255.4 + 72.8
108	3870.7 + 53.2	5828.1 + 16.2	6894.9 + 7.6	7357.6 + 46.3
112	2521.1 + 44.3	4528.3 + 152.2	5292.4 + 32.9	5722.1 + 161.3
115	2979.5 + 6.4	5338.1 + 30.4	6586.3 + 113.0	7319.5 + 37.0
118	2772.7 + 49.4	4813.7 + 97.9	6144.9 + 81.2	6716.2 + 12.4
120	2445.8 + 11.0	4273.0 + 9.8	5239.3 + 33.3	5650.4 + 39.1
122	3513.8 + 64.9	5458.7 + 25.4	7290.1 + 133.6	8517.4 + 13.4

Fourth Set - Start July 9, 1975

Site	3 Months	6 Months	12 Months	21 Months
103	4258.0 + 10.2	5183.9 + 13.0	6682.3 + 61.8	7161.7 + 47.6
105	3326.1 + 2.6	3853.1 + 22.9	4669.0 + 12.8	4942.9 + 42.0
106	3551.6 + 29.8	4625.2 + 55.5	5749.0 + 81.5	6126.4 + 62.3
108	4267.8 + 67.8	5217.8 + 29.8	6854.2 + 133.2	7763.8 + 107.1
112	3081.5 + 18.2	4294.0 + 41.1	5273.8 + 98.5	6045.0 + 25.9
115	3984.6 + 14.1	5090.5 + 71.6	6744.8 + 83.6	7570.8 + 54.0
118	3812.7 + 13.1	4685.1 + 56.7	6337.5 + 59.9	7239.2 + 9.6
120	3105.8 + 2.8	4161.8 + 78.1	5483.8 + 6.2	6202.8 + 143.3
122	3902.9 + 36.6	5314.1 + 32.6	7583.0 + 239.5	8596.1 + 36.8

Table 7. Corrosion Parameters n and k for Weathering Steel
(k in mg/cm^2 month)

Site	First Set		Second Set		Third Set		Fourth Set	
	n	k	n	k	n	k	n	k
103	0.58	8.1	0.53	6.8	0.51	6.3	0.67	9.5
105	0.52	5.1	0.49	5.0	0.55	4.8	0.76	8.2
106	0.51	4.8	0.35	4.0	0.46	5.0	0.65	7.8
108	0.53	7.0	0.38	4.4	0.59	8.0	0.67	9.5
112	0.48	4.8	0.52	5.5	0.73	8.9	0.66	7.4
115	0.44	5.4	0.35	4.8	0.64	8.9	0.64	8.7
118	0.41	4.4	0.29	3.9	0.44	4.8	0.64	8.1
120	0.58	5.9	0.51	5.0	0.58	5.9	0.70	8.1
122	0.48	6.5	0.50	6.9	0.58	8.4	0.64	9.7
Average	0.50 +0.05	5.8 +1.0	0.44 +0.08	5.1 +0.8	0.56 +0.07	6.8 +1.6	0.67 +0.03	8.6 +0.7

Note: $k = 1.0 \text{ mg}/\text{cm}^2$ month corresponds to $15.25 \text{ } \mu\text{m}/\text{yr}$.

Table 8. Integral Corrosion Rates V_i (mg/cm² month) for Weathering Steel
(Area = 310 cm²)

First Set - Start October 15, 1974

<u>Site</u>	<u>3 Months</u>	<u>6 Months</u>	<u>12 Months</u>	<u>24 Months</u>	<u>30 Months</u>
103	4.10	2.91	2.25	1.30	1.07
105	2.87	2.06	1.55	0.89	0.72
106	2.81	1.94	1.70	0.99	0.82
108	3.84	2.57	2.19	1.34	1.09
112	2.69	2.05	1.60	1.01	0.81
115	3.38	2.46	2.06	1.33	1.10
118	2.76	1.99	1.80	1.20	0.99
120	2.62	1.87	1.55	0.95	0.80
122	3.14	2.29	2.10	1.45	1.19

Note: 1.0 mg/cm² mo $\approx$ 15.25 μ m/year

Second Set - Start January 15, 1975

<u>Site</u>	<u>3 Months</u>	<u>6 Months</u>	<u>12 Months</u>	<u>24 Months</u>
103	3.76	3.02	2.14	1.23
105	2.98	2.16	1.48	0.84
106	2.70	2.31	1.65	0.94
108	3.19	2.96	2.14	1.25
112	2.63	2.22	1.56	0.97
115	3.21	2.59	2.03	1.23
118	2.76	2.32	1.84	1.11
120	2.39	1.98	1.51	0.91
122	2.64	2.82	2.08	1.36

Table 8 (Continued)

Third Set - Start April 15, 1975

<u>Site</u>	<u>3 Months</u>	<u>6 Months</u>	<u>12 Months</u>	<u>15 Months</u>
103	3.55	2.99	1.76	1.50
105	2.55	2.01	1.20	1.05
106	2.98	2.74	1.64	1.35
108	4.16	3.13	1.85	1.58
112	2.71	2.43	1.42	1.23
115	3.20	2.87	1.77	1.57
118	2.98	2.59	1.65	1.44
120	2.63	2.29	1.41	1.22
122	3.78	2.93	1.96	1.83

Fourth Set - Start July 9, 1975

<u>Site</u>	<u>3 Months</u>	<u>6 Months</u>	<u>12 Months</u>	<u>21 Months</u>
103	4.60	2.79	1.80	1.10
105	3.58	2.07	1.26	0.76
106	3.82	2.49	1.55	0.94
108	4.59	2.81	1.84	1.19
112	3.31	2.31	1.42	0.93
115	4.28	2.74	1.81	1.16
118	4.10	2.52	1.70	1.11
120	3.33	2.24	1.47	0.95
122	4.20	2.80	2.04	1.32

Table 9. Differential Corrosion Rates ($\mu\text{m}/\text{yr}$) for Weathering Steel Calculated According to Eq. (5)

First Set

<u>Site #</u>	<u>3 Mo.</u>	<u>6 Mo.</u>	<u>12 Mo.</u>	<u>18 Mo.</u>	<u>24 Mo.</u>	<u>30 Mo.</u>
103	27.4	18.4	12.3	9.7	8.2	7.2
105	21.1	14.7	10.3	8.3	7.2	6.4
106	20.5	14.4	10.1	8.2	7.1	6.3
108	28.0	19.4	13.4	10.8	9.3	8.3
112	22.5	16.1	11.5	9.5	8.3	7.4
115	28.4	21.0	15.5	12.9	11.4	10.3
118	25.2	19.0	14.3	12.1	10.8	9.8
120	20.0	13.4	8.9	7.1	6.0	5.3
122	30.4	21.8	15.6	12.9	11.2	10.1

Second Set

<u>Site #</u>	<u>3 Mo.</u>	<u>6 Mo.</u>	<u>12 Mo.</u>	<u>18 Mo.</u>	<u>24 Mo.</u>	<u>30 Mo.</u>
103	27.2	18.9	13.1	10.5	9.0	8.0
105	22.7	16.2	11.5	9.4	8.2	7.3
106	27.0	21.2	16.6	14.4	13.0	12.1
108	27.4	21.1	16.2	13.9	12.4	11.4
112	22.7	16.9	11.1	9.0	7.7	6.9
115	32.4	25.4	19.9	17.3	15.6	14.5
118	30.7	25.1	20.5	18.3	16.8	15.7
120	21.3	15.0	10.5	8.6	7.4	6.6
122	30.4	21.5	15.2	12.4	10.7	9.6

Table 9 (Continued)

Third Set

<u>Site #</u>	<u>3 Mo.</u>	<u>6 Mo.</u>	<u>12 Mo.</u>	<u>18 Mo.</u>	<u>24 Mo.</u>	<u>30 Mo.</u>
103	26.9	18.9	13.3	10.8	9.3	8.3
105	18.0	12.3	8.4	6.7	5.7	5.1
106	24.8	18.1	13.1	10.9	9.5	8.6
108	26.2	17.4	11.5	9.1	7.7	6.7
112	16.4	9.9	6.0	4.4	3.6	3.1
115	24.2	15.5	10.0	7.7	6.4	5.5
118	25.3	18.6	13.7	11.5	10.1	9.2
120	20.0	13.4	8.9	7.1	6.0	5.3
122	28.4	19.0	12.7	10.1	8.5	7.5

Fourth Set

<u>Site #</u>	<u>3 Mo.</u>	<u>6 Mo.</u>	<u>12 Mo.</u>	<u>18 Mo.</u>	<u>14 Mo.</u>	<u>30 Mo.</u>
103	22.9	14.4	9.0	6.9	5.7	4.9
105	13.0	7.7	4.5	3.3	2.7	2.3
106	20.4	13.0	8.3	6.4	5.3	4.6
108	22.9	14.4	9.0	6.9	5.7	4.9
112	18.6	11.8	7.4	5.7	4.7	4.1
115	23.6	25.2	9.7	7.5	6.2	5.4
118	22.0	14.1	9.1	7.0	5.8	5.0
120	17.2	10.6	6.5	4.9	4.0	3.4
122	16.4	16.9	10.9	8.4	7.0	6.0

Table 10. Weight Loss of House Paint on Stainless Steel (mg)
(Average of 3 Samples)

I. Latex Base Exposure to North

<u>Site #</u>	<u>3 Mo.</u>	<u>6 Mo.</u>	<u>12 Mo.</u>	<u>24 Mo.</u>	<u>30 Mo.</u>
103	19.7 $\pm$ 4.1	22.6 $\pm$ 5.4	60.3 $\pm$ 7.2	86.1 $\pm$ 3.0	112.7 $\pm$ 1.5
105	14.8 $\pm$ 5.1	19.7 $\pm$ 4.5	50.9 $\pm$ 2.7	102.2 $\pm$ 2.8	116.6 $\pm$ 3.3
106	18.8 $\pm$ 5.3	20.6 $\pm$ 2.4	55.1 $\pm$ 1.0	95.7 $\pm$ 4.2	121.8 $\pm$ 5.1
108	16.0 $\pm$ 1.2	30.4 $\pm$ 7.1	67.5 $\pm$ 2.2	123.2 $\pm$ 2.8	139.4 $\pm$ 2.6
112	25.9 $\pm$ 1.3	22.8 $\pm$ 3.0	53.5 $\pm$ 5.1	96.0 $\pm$ 2.7	116.8 $\pm$ 7.0
115	21.9 $\pm$ 3.7	30.1 $\pm$ 2.3	69.5 $\pm$ 0.3	132.6 $\pm$ 4.5	169.2 $\pm$ 0.3
118	20.1 $\pm$ 2.8	27.9 $\pm$ 2.1	81.3 $\pm$ 12.4	140.8 $\pm$ 3.1	179.2 $\pm$ 7.3
120	22.0 $\pm$ 1.9	24.4 $\pm$ 4.7	67.2 $\pm$ 3.0	120.7 $\pm$ 1.4	156.1 $\pm$ 6.1
122	26.5 $\pm$ 5.5	28.1 $\pm$ 1.4	73.3 $\pm$ 3.6	147.1 $\pm$ 8.2	178.1 $\pm$ 1.5

II. Latex Base Exposure to South

<u>Site #</u>	<u>3 Mo.</u>	<u>6 Mo.</u>	<u>12 Mo.</u>	<u>24 Mo.</u>	<u>30 Mo.</u>
103	23.1 $\pm$ 4.1	30.3 $\pm$ 6.6	77.2 $\pm$ 4.4	139.2 $\pm$ 8.8	160.1 $\pm$ 6.5
105	13.7 $\pm$ 1.2	19.8 $\pm$ 2.0	66.3 $\pm$ 3.1	131.7 $\pm$ 2.8	154.8 $\pm$ 3.3
106	16.4 $\pm$ 1.7	24.1 $\pm$ 1.0	68.7 $\pm$ 3.1	137.5 $\pm$ 3.0	82.9 $\pm$ 0.5
108	24.2 $\pm$ 4.4	27.6 $\pm$ 6.8	88.6 $\pm$ 4.6	160.8 $\pm$ 9.1	160.8 $\pm$ 9.1
112	18.6 $\pm$ 1.3	21.5 $\pm$ 2.5	74.1 $\pm$ 0.2	125.4 $\pm$ 1.7	155.5 $\pm$ 3.0
115	17.2 $\pm$ 1.2	33.3 $\pm$ 3.0	82.4 $\pm$ 1.4	166.5 $\pm$ 3.4	204.6 $\pm$ 3.1
118	18.3 $\pm$ 3.3	26.5 $\pm$ 4.0	81.5 $\pm$ 1.9	160.5 $\pm$ 2.7	197.1 $\pm$ 1.1
120	18.9 $\pm$ 0.1	25.6 $\pm$ 2.5	78.9 $\pm$ 2.9	152.4 $\pm$ 2.6	171.4 $\pm$ 5.2
122	27.2 $\pm$ 4.9	30.2 $\pm$ 1.9	97.7 $\pm$ 4.9	195.0 $\pm$ 6.6	231.4 $\pm$ 1.0

Table 10. (Continued)

III. Oil Base, Exposure to North

<u>Site #</u>	<u>3 Mo.</u>	<u>6 Mo.</u>	<u>12 Mo.</u>	<u>24 Mo.</u>	<u>30 Mo.</u>
103	19.1 $\pm$ 1.1	25.5 $\pm$ 1.2	63.9 $\pm$ 2.6	79.7 $\pm$ 2.4	93.1 $\pm$ 5.2
105	18.2 $\pm$ 0.9	19.7 $\pm$ 0.4	57.9 $\pm$ 4.0	79.9 $\pm$ 5.7	95.8 $\pm$ 4.4
106	15.6 $\pm$ 1.6	16.7 $\pm$ 1.4	49.6 $\pm$ 5.2	64.9 $\pm$ 1.4	82.9 $\pm$ 0.5
108	16.0 $\pm$ 0.7	19.3 $\pm$ 0.7	60.7 $\pm$ 0.4	82.3 $\pm$ 1.9	90.5 $\pm$ 6.0
112	15.9 $\pm$ 0.5	19.6 $\pm$ 0.4	51.8 $\pm$ 0.6	72.7 $\pm$ 2.7	76.4 $\pm$ 3.5
115	18.2 $\pm$ 0.7	21.2 $\pm$ 2.4	62.1 $\pm$ 2.8	79.9 $\pm$ 5.9	83.4 $\pm$ 6.4
118	18.4 $\pm$ 0.5	23.5 $\pm$ 5.0	67.0 $\pm$ 0.5	78.7 $\pm$ 5.1	92.0 $\pm$ 2.5
120	18.1 $\pm$ 1.0	19.0 $\pm$ 0.9	64.7 $\pm$ 2.3	78.7 $\pm$ 2.1	87.1 $\pm$ 0.8
122	19.5 $\pm$ 0.6	20.9 $\pm$ 0.4	67.5 $\pm$ 2.8	89.4 $\pm$ 2.8	104.1 $\pm$ 3.6

IV Oil Base, Exposure to South

<u>Site #</u>	<u>3 Mo.</u>	<u>6 Mo.</u>	<u>12 Mo.</u>	<u>24 Mo.</u>	<u>30 Mo.</u>
103	19.5 $\pm$ 1.1	23.7 $\pm$ 0.8	70.4 $\pm$ 2.2	96.5 $\pm$ 3.4	105.3 $\pm$ 8.5
105	21.1 $\pm$ 1.6	22.3 $\pm$ 0.5	66.9 $\pm$ 3.0	96.6 $\pm$ 3.9	113.5 $\pm$ 3.4
106	15.6 $\pm$ 0.3	18.3 $\pm$ 0.3	57.7 $\pm$ 1.5	76.7 $\pm$ 0.0	90.0 $\pm$ 3.5
108	17.3 $\pm$ 0.6	21.0 $\pm$ 1.5	66.8 $\pm$ 2.7	94.2 $\pm$ 0.9	106.3 $\pm$ 2.2
112	17.6 $\pm$ 1.2	22.0 $\pm$ 1.8	58.5 $\pm$ 0.9	80.9 $\pm$ 1.0	97.4 $\pm$ 3.4
115	19.0 $\pm$ 0.6	21.1 $\pm$ 0.6	64.0 $\pm$ 1.5	92.0 $\pm$ 1.9	99.7 $\pm$ 3.1
118	18.5 $\pm$ 0.4	21.0 $\pm$ 0.6	70.4 $\pm$ 2.0	92.7 $\pm$ 3.0	101.3 $\pm$ 1.1
120	19.1 $\pm$ 1.4	22.0 $\pm$ 1.7	67.4 $\pm$ 0.4	88.4 $\pm$ 4.4	105.8 $\pm$ 3.3
122	19.8 $\pm$ 0.3	22.4 $\pm$ 1.0	68.8 $\pm$ 5.0	93.9 $\pm$ 1.0	105.7 $\pm$ 3.3

Table 11. Integral Corrosion Rates V_i ($\mu\text{g}/\text{cm}^2$ month) for House Paint (Area = 155 cm^2)

I. Latex Facing North

<u>Site</u>	<u>3 Months</u>	<u>6 Months</u>	<u>12 Months</u>	<u>12 Months</u>	<u>30 Months</u>
103	42.6	24.3	32.4	23.1	24.2
105	31.8	21.2	27.4	27.5	25.1
106	40.4	22.2	29.6	25.7	26.2
108	34.4	32.7	36.3	33.1	30.0
112	55.7	24.5	28.8	25.8	25.1
115	47.1	32.4	37.4	35.6	36.4
118	43.2	30.0	43.7	37.8	38.5
120	47.3	26.2	36.1	32.4	33.6
122	57.0	30.2	39.4	39.5	38.3

II. Latex Base Facing South

<u>Site #</u>	<u>3 Months</u>	<u>6 Months</u>	<u>12 Months</u>	<u>24 Months</u>	<u>30 Months</u>
103	49.6	32.6	41.5	37.4	34.4
105	29.5	21.3	35.6	35.4	33.3
106	35.3	25.9	36.9	37.0	34.1
108	52.0	29.7	47.6	43.6	39.7
112	40.0	23.1	34.8	33.7	33.4
115	37.0	35.8	44.3	44.8	44.0
118	39.4	28.5	43.8	43.1	42.4
120	40.6	27.5	42.4	41.0	36.9
122	58.5	32.5	52.5	52.4	49.8

Table 11 (Continued)

III. Oil Base Facing North

<u>Site #</u>	<u>3 Months</u>	<u>6 Months</u>	<u>12 Months</u>	<u>24 Months</u>	<u>30 Months</u>
103	41.1	27.4	34.4	21.4	20.0
105	39.1	21.1	31.1	21.5	20.6
106	33.5	18.0	26.7	17.4	17.8
108	34.4	20.7	32.6	22.1	19.5
112	34.2	20.7	27.8	19.5	16.4
115	39.1	22.8	33.4	21.5	17.9
118	39.6	25.3	36.0	21.2	19.8
120	38.9	20.4	34.8	21.2	18.7
122	41.9	22.5	36.3	24.0	22.4

IV. Oil Base Facing South

<u>Site #</u>	<u>3 Months</u>	<u>6 Months</u>	<u>12 Months</u>	<u>24 Months</u>	<u>30 Months</u>
103	41.9	25.5	37.8	25.9	22.6
105	45.4	24.0	36.0	26.0	24.4
106	33.5	19.7	31.0	20.6	19.4
108	37.2	22.6	35.9	25.3	22.9
112	37.8	23.7	31.5	21.7	20.9
115	40.9	22.7	34.4	24.7	21.4
118	39.8	22.6	37.8	24.9	21.8
120	41.1	23.7	35.2	23.8	22.8
122	42.6	24.1	37.0	25.2	22.7

Table 12. Weight Loss Data for Marble (mg)
(Average of 3 Samples)

<u>Site #</u>	<u>3 Mo.</u>	<u>6 Mo.</u>	<u>12 Mo.</u>	<u>24 Mo.</u>	<u>30 Mo.</u>
103	303	480	1282	1549	1787
105	366	584	1074	1746	1912
106	328	554	989	1472	1689
108	379	636	1235	1675	2109
112	349	565	1128	1601	1786
115	397	685	1093	1655	1949
118	373	664	1074	1710	1974
120	394	647	1055	1551	1806
122	486	679	1273	1791	2091

Table 13. Corrosion Rates V_i ($\mu\text{g}/\text{cm}^2$ month) for
Marble (Total Area = 366 cm^2)

<u>Site #</u>	<u>3 Mo.</u>	<u>6 Mo.</u>	<u>12 Mo.</u>	<u>24 Mo.</u>	<u>30 Mo.</u>
103	276	219	292	176	163
105	333	266	245	199	174
106	299	252	225	168	154
108	345	290	281	191	192
112	318	257	257	182	163
115	362	312	249	188	178
118	340	302	245	195	180
120	359	295	240	177	164
122	443	309	290	204	190

Table 14a. Average Reflectance Loss (%) for Ag, First Year
(Average of 4 Measurements per Sample,
Duplicate Samples)

<u>Site #</u>	<u>3 Months</u>	<u>6 Months</u>	<u>9 Months</u>	<u>12 Months</u>
103	38.3 $\pm$ 2.3	57.9 $\pm$ 8.9	70.7 $\pm$ 4.7	67.7 $\pm$ 4.5
105	27.6 $\pm$ 5.0	55.8 $\pm$ 1.2	70.2 $\pm$ 4.7	78.4 $\pm$ 4.5
106	16.7 $\pm$ 0.8	31.9 $\pm$ 5.2	52.5 $\pm$ 9.8	62.0 $\pm$ 10.3
108	66.0 $\pm$ 0.8	74.7 $\pm$ 1.6	65.0 $\pm$ 0.8	73.7 $\pm$ 1.8
112	21.6 $\pm$ 0.7	36.4 $\pm$ 0.4	51.4 $\pm$ 1.7	56.6 $\pm$ 6.0
115	74.1 $\pm$ 3.8	66.2 $\pm$ 1.4	83.5 $\pm$ 0.7	81.5 $\pm$ 3.7
118	21.4 $\pm$ 0.3	36.5 $\pm$ 6.8	61.2 $\pm$ 0.4	51.9 $\pm$ 2.3
120	23.3 $\pm$ 0.7	42.8 $\pm$ 1.4	56.9 $\pm$ 0.1	60.5 $\pm$ 6.6
122	63.4 $\pm$ 0.3	58.4 $\pm$ 0.8	67.0 $\pm$ 2.7	66.2 $\pm$ 0.5

Table 14b. Reflectance Loss and Film Thickness for Ag, First Year
(Values Correspond to one of the Duplicate Samples in
Table 14a)

<u>Site #</u>	<u>3 Months</u>		<u>6 Months</u>		<u>9 Months</u>		<u>12 Months</u>	
	RL(%)	d(Å)	RL(%)	d(Å)	RL(%)	d(Å)	RL(%)	d(Å)
103	41	202	67	312	75	409	72	334
105	33	163	54	252	66	322	77	340
106	17	133	37	151	43	155	72	324
108	67	386	73	445	66	379	72	407
112	21	127	36	150	53	188	63	212
115	78	382	64	266	84	395	78	311
118	21	122	41	171	62	209	54	186
120	23	149	44	189	57	231	67	232
122	63	296	69	359	70	306	67	215

Table 15a. Average Reflectance Loss (%) for Ag, Second Year
(Average of 4 Measurements per Sample, Duplicate Samples)

Site #	3 Months	6 Months	9 Months	12 Months
103	36.4 $\pm$ 0.3	48.9 $\pm$ 0.6	65.1 $\pm$ 5.2	76.6 $\pm$ 2.7
105	26.5 $\pm$ 1.9	44.5 $\pm$ 5.2	54.5 $\pm$ 0.2	77.0 $\pm$ 0.2
106	23.3 $\pm$ 4.2	40.7 $\pm$ 4.5	53.8 $\pm$ 0.0	68.8 $\pm$ 0.4
108	75.1 $\pm$ 4.5	79.9 $\pm$ 4.0	87.2 $\pm$ 5.1	93.6 $\pm$ 0.2
112	25.9 $\pm$ 0.0	n.d.	55.3 $\pm$ 6.8	66.4 $\pm$ 4.6
115	52.8 $\pm$ 4.3	72.2 $\pm$ 9.2	87.6 $\pm$ 1.0	87.0 $\pm$ 4.0
118	33.4 $\pm$ 0.4	55.0 $\pm$ 2.0	62.6 $\pm$ 5.8	77.6 $\pm$ 3.4
120	30.1 $\pm$ 0.0	58.5 $\pm$ 1.9	70.9 $\pm$ 3.6	80.0 $\pm$ 1.4
122	57.2 $\pm$ 10.6	75.7 $\pm$ 7.1	82.3 $\pm$ 0.6	86.4 $\pm$ 3.5

n.d. = not determined

Table 15b. Reflectance Loss and Film Thickness for Ag, Second Year
(Values Correspond to one of the Duplicate Samples in Table 15a)

Site #	3 Months		6 Months		9 Months		12 Months	
	RL(%)	d(Å)	RL(%)	d(Å)	RL(%)	d(Å)	RL(%)	d(Å)
103	36.1	166	54.4	220	70.2	325	79.3	471
105	28.4	154	49.6	173	54.3	247	77.2	423
106	27.4	145	45.2	161	53.8	161	68.4	298
108	79.6	370	75.9	n.d.	92.3	730	93.8	883
112	25.9	130	n.d.	164	48.5	182	71.0	289
115	48.5	167	63.0	240	86.6	370	91.0	500
118	33.8	181	57.0	211	56.8	223	74.2	325
120	30.1	151	56.6	195	67.3	257	81.5	376
122	46.6	154	68.6	248	81.7	389	82.9	494

Table 16. Time-To-Failure of A1 Tension Samples (Days)

I. 50% of All Samples

<u>Site #</u>	<u>A1 7079</u> <u>25 Ksi</u>	<u>A1 7079</u> <u>15 Ksi</u>	<u>A1 2014</u> <u>45 Ksi</u>	<u>A1 2014</u> <u>25 Ksi</u>
103	125	224	<48	575
105	150	245	60	450
106	160	370	230	
108	165	250	<48	
112	210	270	410	
115	225	270	100	
118	160	260	105	822
120	155	320	75	755
122	160	133	75	822

II. 100% of All Samples

103	172	382	66	(2)*
105	160	360	230	822
106	210	622	505	(8)
108	210	381	225	871
112	240	622	(1)	(6)
115	255	346	(1)	(7)
118	220	630	155	(1)
120	224	(1)	83	(3)
122	201	277	814	(4)

* Number of samples left.

Table 17. Results of Nylon Exposure

<u>Site #</u>	<u>Sample w/Holes</u>	<u>No. of Holes</u>	<u>Remarks</u>
<u>1st Set, Start October 1965</u>			
120	1	6	
<u>2nd Set, Start January 1976</u>			
108	1	1	
118	2	8	
<u>3rd Set, Start April 1976</u>			
103	2	1	Severe damage on other sample
106	1	3	
108	2	3	Severe damage on other sample
112	2	4	Severe damage on other sample
115	1	1	
118	2	4	
120	2		Severe damage on both samples
122	2	10	
<u>4th Set, Start July 1976</u>			
103	1	6	
105	1	1	
106	1	7	
108	2	1	Severe damage on other sample
112	2	10	
120	2	17	
122	1	2	

Table 18. Quarterly Averages of Air Quality Data for the Period
Between Nov. 10, 1974 and March 31, 1977

Key:

WS = wind speed (m/sec)
WD = wind direction (degrees)
T = temperature ($^{\circ}\text{C}$)
Ozone (ppb)
THC = total hydrocarbon (ppm)
NOX (ppb)
TS = total sulfur (ppb)
H₂S, SO₂ (ppb)
RH = relative humidity (%)

Table 18 (Continued)

I. Average for the Period Nov. 10, 1974 through Jan. 14, 1975

<u>Site #</u>	<u>WS</u>	<u>WD</u>	<u>T</u>	<u>Ozone</u>	<u>THC</u>	<u>NOx</u>	<u>TS</u>	<u>H₂S</u>	<u>SO₂</u>	<u>RH</u>
103	4.04	217	2.92	7.1	1.56	41.3	31.8	2.5	32.6	70.9
105	3.81	212	3.33	7.8	2.29	49.8	22.6	7.4	14.5	69.7
106	3.90	211	3.46	6.6	1.84	40.3	32.9	2.5	31.7	71.1
108	3.93	205	2.62	9.5	1.93	36.5	52.8	2.5	44.9	72.4
112	4.37	215	3.34	7.6	1.76	44.0	11.5	n.d.	n.d.	83.6
115	3.75	202	2.64	12.5	1.41	20.4	50.7	2.5	46.6	81.0
118	3.50	209	2.74	17.0	1.38	14.7	7.0	n.d.	n.d.	68.6
120	4.44	213	2.73	9.2	1.72	35.4	8.3	2.6	8.7	73.5
122	4.92	203	1.61	15.7	1.74	10.7	63.3	2.5	42.7	75.6

II. Averages for Period Jan. 15, 1975 through Apr. 14, 1975

<u>Site #</u>	<u>WS</u>	<u>WD</u>	<u>T</u>	<u>Ozone</u>	<u>THC</u>	<u>NOX</u>	<u>TS</u>	<u>H₂S</u>	<u>SO₂</u>	<u>RH</u>
103	4.63	192	3.01	19.2	1.66	20.8	13.8	3.2	11.4	75.4
105	4.10	195	3.48	16.3	2.37	54.4	21.7	12.8	15.7	69.2
106	4.64	188	3.43	16.0	1.82	50.7	49.8	-	46.5	73.9
108	4.19	187	2.67	21.6	1.84	31.7	38.0	13.8	35.6	70.8
112	4.31	187	3.52	17.7	1.64	43.5	12.9	n.d.	n.d.	67.7
115	4.12	190	2.75	24.5	1.41	15.5	47.4	-	44.1	78.2
118	3.70	187	3.02	26.8	1.29	19.4	9.2	n.d.	n.d.	73.6
120	4.20	190	3.02	21.5	1.69	32.3	9.4	2.8	8.8	68.7
122	5.16	134	1.97	32.8	1.71	8.4	46.1	-	34.0	67.6

n.d. - not determined.

Table 18 (Continued)

III. Averages for Period Apr. 15, 1975 through July 8, 1975

<u>Site #</u>	<u>WS</u>	<u>WD</u>	<u>T</u>	<u>Ozone</u>	<u>THC</u>	<u>NOX</u>	<u>TS</u>	<u>H₂S</u>	<u>SO₂</u>	<u>RH</u>
103	4.22	184	21.2	34.1	1.95	30.1	10.8	3.3	8.5	40.0
105	2.99	171	22.2	32.4	2.17	38.3	13.7	14.2	10.6	57.4
106	3.48	184	21.9	36.0	1.86	32.0	23.6	5.5	23.6	69.0
108	3.32	191	21.0	34.9	1.87	24.9	6.5	6.6	6.3	63.8
112	3.21	196	21.8	32.7	1.54	35.4	9.2	n.d.	n.d.	60.4
115	3.06	170	20.8	35.1	1.41	12.5	34.1	2.9	21.4	72.7
118	3.19	167	21.1	55.3	1.32	10.3	5.6	n.d.	n.d.	61.6
120	4.47	158	19.9	39.2	1.84	31.2	11.4	2.8	5.4	65.0
122	4.48	237	19.2	47.3	1.64	6.1	21.6	5.1	12.7	69.2

IV. Averages for Period July 9, 1975 through Oct. 14, 1975

<u>Site #</u>	<u>WS</u>	<u>WD</u>	<u>T</u>	<u>Ozone</u>	<u>THC</u>	<u>NOX</u>	<u>TS</u>	<u>H₂S</u>	<u>SO₂</u>	<u>RH</u>
103	3.80	189	21.6	20.1	2.20	32.9	11.1	11.2	9.5	52.6
105	3.04	191	22.5	25.1	2.25	43.1	12.0	9.6	9.8	66.8
106	3.16	194	22.1	27.9	2.20	48.6	8.7	4.3	11.6	66.4
108	2.37	181	20.1	24.8	1.98	34.5	8.8	2.6	8.5	60.7
112	2.63	196	20.7	26.4	1.89	62.5	16.2	n.d.	n.d.	60.4
115	2.30	167	21.1	34.9	1.70	19.1	50.3	120	28.8	70.0
118	3.55	163	20.9	40.8	1.51	14.1	7.6	n.d.	n.d.	58.3
120	2.86	177	19.8	33.9	2.04	27.2	5.8	9.2	5.2	68.6
122	3.57	190	19.4	37.5	1.63	9.0	6.9	3.6	6.0	60.5

Table 18 (Continued)

V. Averages for Period Oct. 15, 1975 through Jan. 14, 1976

<u>Site #</u>	<u>WS</u>	<u>WD</u>	<u>T</u>	<u>Ozone</u>	<u>THC</u>	<u>NOX</u>	<u>TS</u>	<u>H₂S</u>	<u>SO₂</u>	<u>RH</u>
103	5.30	201	5.62	12.0	1.92	44.3	16.1	5.9	13.0	61.1
105	4.32	200	6.39	10.9	2.29	49.5	14.1	7.7	11.2	61.7
106	3.93	202	5.95	13.4	2.27	84.4	16.4	11.0	13.5	67.2
108	4.67	187	5.49	19.9	2.19	38.8	15.6	4.9	14.0	59.2
112	3.92	202	6.38	12.2	1.82	58.4	19.6	n.d.	n.d.	58.1
115	3.91	187	5.50	19.8	1.62	22.6	67.0	126	44.6	72.7
118	4.07	189	6.08	23.1	1.73	16.0	8.0	n.d.	n.d.	69.5
120	4.62	198	5.36	14.3	1.80	35.2	9.0	12.8	7.7	64.7
122	5.63	199	5.02	21.3	1.74	15.7	14.6	3.4	12.2	69.6

VI. Averages for Period Jan. 15, 1976 through Apr. 14, 1976

<u>Site #</u>	<u>WS</u>	<u>WD</u>	<u>T</u>	<u>Ozone</u>	<u>THC</u>	<u>NOX</u>	<u>TS</u>	<u>H₂S</u>	<u>SO₂</u>	<u>RH</u>
103	5.80	200	7.30	22.3	2.05	44.8	14.3	3.6	12.1	55.2
105	5.00	196	8.19	18.7	2.12	52.3	15.7	7.2	12.8	64.9
106	4.63	203	8.30	19.4	2.19	47.9	18.0	6.0	13.6	66.2
108	4.88	193	7.33	22.0	2.02	39.2	13.6	3.6	11.5	70.1
112	4.59	198	8.18	20.8	1.84	49.8	14.7	n.d.	n.d.	64.5
115	4.27	184	6.97	26.0	1.60	16.4	14.4	22.7	8.8	69.4
118	4.34	189	7.77	29.5	1.57	13.7	7.4	n.d.	n.d.	68.2
120	5.22	195	7.07	21.1	1.77	32.6	11.8	9.3	8.8	59.3
122	5.97	201	6.29	34.7	1.86	11.2	13.3	7.6	10.6	69.8

Table 18 (Continued)

VII. Averages for Period Apr. 15, 1976 through July 14, 1976

<u>Site #</u>	<u>WS</u>	<u>WD</u>	<u>T</u>	<u>Ozone</u>	<u>THC</u>	<u>NOX</u>	<u>TS</u>	<u>H₂S</u>	<u>SO₂</u>	<u>RH</u>
103	4.51	181	20.1	35.5	1.95	37.8	11.0	6.2	9.0	52.5
105	3.94	177	20.9	35.8	2.16	43.1	19.0	8.7	17.1	69.6
106	3.46	183	20.8	33.2	2.09	42.6	14.8	3.5	14.6	63.2
108	3.66	179	19.9	37.5	1.95	31.7	10.0	3.0	9.1	63.6
112	3.47	186	20.1	34.1	1.92	41.8	7.7	n.d.	n.d.	73.2
115	3.17	164	19.6	42.3	1.61	14.7	9.3	14.1	5.9	68.3
118	3.32	165	19.4	48.4	1.65	13.3	7.7	n.d.	n.d.	71.8
120	4.02	183	19.6	38.5	1.92	30.0	8.8	7.9	7.5	73.9
122	4.38	184	18.6	47.6	1.73	7.4	17.4	13.6	8.7	61.3

VIII. Averages for Period July 15, 1976 through Oct. 14, 1976

<u>Site #</u>	<u>WS</u>	<u>WD</u>	<u>T</u>	<u>Ozone</u>	<u>THC</u>	<u>NOX</u>	<u>TS</u>	<u>H₂S</u>	<u>SO₂</u>	<u>RH</u>
103	3.86	174	21.8	35.1	2.20	59.2	8.8	2.6	7.5	52.0
105	3.33	166	22.8	34.9	2.42	50.2	19.4	2.6	14.7	65.5
106	2.96	172	22.5	34.8	2.29	50.8	16.4	2.5	14.6	62.1
108	3.03	168	21.2	36.8	2.16	43.1	26.0	5.1	13.6	72.3
112	3.00	177	22.1	32.6	2.21	52.0	8.8	n.d.	n.d.	70.1
115	2.60	152	21.1	49.0	1.82	18.1	15.1	8.3	7.3	62.0
118	2.78	158	21.5	51.6	1.75	16.1	8.3	n.d.	n.d.	68.2
120	3.14	171	21.3	39.4	2.12	34.9	14.4	8.8	8.2	66.1
122	2.46	174	20.0	45.2	1.76	14.3	19.8	2.6	7.8	66.7

Table 18 (Continued)

IX. Averages for Period Oct. 15, 1976 through Jan. 14, 1977

<u>Site #</u>	<u>WS</u>	<u>WD</u>	<u>T</u>	<u>Ozone</u>	<u>THC</u>	<u>NOX</u>	<u>TS</u>	<u>H₂S</u>	<u>SO₂</u>	<u>RH</u>
103	4.83	232	1.42	20.0	1.99	54.3	11.9	2.8	11.2	66.6
105	3.96	222	2.43	8.7	2.41	66.2	22.2	3.3	15.7	71.1
106	3.83	226	1.83	8.0	2.36	71.8	23.3	2.5	20.7	66.8
108	3.95	226	1.05	14.1	2.04	47.1	25.4	4.2	16.0	78.5
112	3.53	231	2.00	11.0	2.26	60.9	12.2	n.d.	n.d.	57.1
115	3.55	211	0.76	15.1	1.92	27.3	21.7	8.4	13.6	40.1
118	3.23	212	1.40	17.7	1.94	25.1	12.2	n.d.	n.d.	70.1
120	4.31	233	0.96	11.9	2.16	49.4	18.0	9.9	10.1	70.8
122	3.39	231	-0.32	19.2	1.75	13.0	20.3	2.6	11.4	68.1

X. Averages for Period Jan. 15, 1977 through Mar. 31, 1977

<u>Site #</u>	<u>WS</u>	<u>WD</u>	<u>T</u>	<u>Ozone</u>	<u>THC</u>	<u>NOX</u>	<u>TS</u>	<u>H₂S</u>	<u>SO₂</u>	<u>RH</u>
103	4.85	229	2.67	20.0	1.86	40.4	9.5	2.5	8.7	48.9
105	4.63	222	4.42	17.9	2.28	50.0	18.5	3.0	12.3	90.1
106	4.63	219	6.14	20.9	2.10	42.9	15.0	2.6	12.7	63.5
108	4.87	219	3.06	23.7	1.97	35.3	20.5	2.8	13.5	72.9
112	4.28	228	4.14	20.9	2.10	44.2	11.9	n.d.	n.d.	57.1
115	4.41	205	4.13	29.1	1.78	19.8	14.3	4.9	10.3	47.6
118	4.23	210	3.34	32.3	1.77	14.3	9.6	n.d.	n.d.	72.9
120	5.31	204	3.30	23.3	1.84	32.9	15.4	9.7	8.4	73.5
122	5.75	237	2.04	31.9	1.68	9.0	13.6	2.5	8.5	57.0

Table 19. Quarterly Averages of Total Suspended Particulates, Sulfates and Nitrates ($\mu\text{g}/\text{m}^3$)

I. Jan. 15, 1975 through April 14, 1975

<u>Site #</u>	<u>TSP</u>	<u>SO₄</u>	<u>NO₃</u>
103	90.7 (3)	17.8 (3)	8.6 (3)
105	80.5 (10)	10.4 (10)	5.6 (10)
106	87.6 (7)	12.8 (7)	6.4 (7)
108	59.4 (11)	10.5 (11)	5.7 (11)
112	70.2 (10)	9.8 (10)	5.4 (10)
115	44.3 (6)	10.4 (6)	4.1 (6)
118	55.5 (6)	5.9 (6)	2.8 (6)
120	63.6 (6)	10.9 (6)	5.7 (6)
122	34.8 (11)	7.6 (11)	4.9 (11)

II. April 15, 1975 through July 8, 1975

<u>Site #</u>	<u>TSP</u>	<u>SO₄</u>	<u>NO₃</u>
103	107.8 (17)	12.5 (17)	2.5 (17)
105	97.4 (18)	13.8 (18)	4.2 (18)
106	91.5 (17)	14.5 (17)	3.2 (17)
108	92.2 (23)	15.2 (23)	3.3 (23)
112	98.4 (21)	14.9 (21)	3.0 (21)
115	72.6 (17)	15.9 (17)	2.5 (17)
118	93.4 (23)	12.4 (23)	2.5 (22)
120	95.2 (12)	17.5 (12)	4.8 (12)
122	68.3 (24)	15.7 (24)	2.8 (24)

Values in Brackets Indicate Number of Sample Days

Table 19 (Continued)

III. July 9, 1975 through Oct. 14, 1975

<u>Site #</u>	<u>TSP</u>	<u>SO₄</u>	<u>NO₃</u>
103	100.5 (30)	14.5 (30)	3.1 (30)
105	86.3 (26)	14.4 (26)	3.3 (26)
106	76.1 (20)	17.1 (20)	2.8 (20)
108	94.1 (28)	17.4 (28)	3.9 (20)
112	96.8 (28)	15.5 (28)	3.2 (28)
115	62.9 (26)	14.1 (26)	2.7 (26)
118	61.5 (26)	11.6 (26)	2.2 (26)
120	74.6 (18)	17.3 (18)	3.7 (18)
122	54.0 (27)	13.3 (27)	2.2 (27)

IV. Oct. 15, 1975 through Jan. 14, 1976

<u>Site #</u>	<u>TSP</u>	<u>SO₄</u>	<u>NO₃</u>
103	83.8 (28)	11.1 (28)	4.2 (28)
105	73.3 (30)	10.3 (30)	4.2 (30)
106	60.5 (28)	10.3 (28)	4.0 (28)
108	67.0 (28)	11.6 (28)	4.1 (28)
112	54.5 (30)	10.1 (30)	3.9 (30)
115	41.8 (27)	9.4 (27)	3.8 (27)
118	45.8 (27)	9.9 (27)	3.5 (27)
120	46.6 (23)	8.9 (23)	3.7 (23)
122	38.3 (30)	8.8 (30)	3.3 (30)

Table 19 (Continued)

V. Jan. 15, 1976 through April 14, 1976

<u>Site #</u>	<u>TSP</u>	<u>SO₄</u>	<u>NO₃</u>
103	94.5 (27)	10.2 (27)	4.0 (27)
105	90.2 (17)	9.8 (17)	4.5 (27)
106	78.5 (28)	10.6 (28)	4.2 (27)
108	80.8 (27)	10.8 (27)	4.1 (27)
112	73.6 (28)	8.9 (28)	4.1 (28)
115	46.5 (23)	8.9 (23)	4.3 (23)
118	59.1 (27)	9.2 (28)	3.8 (27)
120	48.7 (28)	8.1 (28)	3.8 (28)
122	46.7 (26)	9.3 (26)	4.5 (26)

VI. April 15, 1976 through July 14, 1976

<u>Site #</u>	<u>TSP</u>	<u>SO₄</u>	<u>NO₃</u>
103	94.5 (26)	14.1 (16)	3.6 (26)
105	86.6 (29)	14.3 (29)	3.6 (29)
106	80.0 (30)	13.0 (30)	3.4 (30)
108	99.3 (29)	14.9 (29)	3.4 (29)
112	80.0 (29)	13.0 (29)	3.2 (29)
115	64.1 (28)	11.7 (29)	2.9 (29)
118	78.9 (29)	11.8 (29)	2.2 (29)
120	53.4 (29)	11.8 (28)	2.7 (28)
122	64.6 (30)	11.6 (31)	3.0 (31)

Table 19 (Continued)

VII. July 15, 1976 through Oct. 14, 1976

<u>Site #</u>	<u>TSP</u>	<u>SO₄</u>	<u>NO₃</u>
103	126.3 (29)	19.6 (29)	4.3 (29)
105	102.9 (30)	17.5 (30)	4.1 (30)
106	90.3 (29)	16.2 (29)	3.3 (29)
108	120.5 (29)	20.2 (29)	4.0 (29)
112	107.1 (29)	17.4 (29)	3.1 (29)
115	72.0 (30)	14.7 (30)	3.1 (29)
118	77.4 (29)	16.9 (29)	3.0 (28)
120	62.6 (26)	14.8 (26)	3.0 (26)
122	69.4 (29)	16.4 (29)	3.2 (28)

VIII. Oct. 15, 1976 through Jan. 14, 1977

<u>Site #</u>	<u>TSP</u>	<u>SO₄</u>	<u>NO₃</u>
103	79.7 (31)	9.7 (31)	4.0 (31)
105	82.5 (31)	9.4 (31)	4.0 (31)
106	71.9 (31)	8.3 (31)	3.5 (31)
108	64.7 (31)	9.1 (31)	3.6 (31)
112	59.0 (31)	7.7 (31)	3.5 (31)
115	55.6 (31)	8.5 (31)	3.5 (31)
118	54.3 (30)	8.7 (31)	3.5 (31)
120	55.6 (31)	7.3 (31)	3.6 (31)
122	55.8 (31)	8.4 (31)	4.2 (31)

Table 19 (Continued)

IX. Jan. 15, 1977 through Mar. 31, 1977

<u>Site #</u>	<u>TSP</u>	<u>SO₄</u>	<u>NO₃</u>
103	74.2 (24)	9.7 (25)	3.6 (25)
105	84.1 (25)	8.7 (25)	4.3 (25)
106	72.8 (25)	7.9 (25)	3.5 (25)
108	75.7 (25)	10.1 (25)	4.3 (25)
112	58.6 (25)	7.4 (25)	3.6 (35)
115	46.0 (25)	8.0 (25)	4.1 (25)
118	44.6 (24)	8.0 (24)	3.6 (24)
120	49.0 (25)	6.9 (25)	3.7 (25)
122	40.1 (25)	7.7 (25)	4.1 (25)

Table 20. Average Concentration for Different Exposure
Periods and Start of Exposure

I. Total Sulfur (ppb)

Start Nov. 10, 1974

<u>Site #</u>	<u>3 Mo.</u>	<u>6 Mo.</u>	<u>12 Mo</u>	<u>24 Mo.</u>	<u>30 Mo.</u>
103	31.8	22.8	16.9	14.7	13.9
105	22.6	22.2	17.6	17.3	17.9
106	32.9	41.3	28.9	22.6	21.9
108	52.8	45.4	26.5	21.4	21.7
112	11.5	12.2	12.5	14.4	13.9
115	50.7	49.1	45.6	36.0	32.4
118	7.0	8.1	7.4	7.6	8.3
120	8.3	8.9	8.7	9.9	11.3
122	63.3	54.7	34.5	25.4	23.7

Start Jan. 15, 1975

<u>Site #</u>	<u>3 Mo.</u>	<u>6 Mo.</u>	<u>12 Mo.</u>	<u>24 Mo.</u>
103	13.8	12.3	12.0	12.2
105	21.7	17.7	15.4	17.2
106	49.8	36.7	24.6	21.4
108	38.0	22.3	17.2	18.0
112	12.9	11.1	14.5	13.2
115	47.4	40.8	49.7	32.4
118	9.2	7.4	7.6	8.3
120	9.4	10.4	8.9	11.1
122	46.1	33.9	22.3	20.0

Table 20 (Continued)

Start Apr. 15, 1975

<u>Site #</u>	<u>3 Mo.</u>	<u>6 Mo.</u>	<u>12 Mo</u>	<u>15 Mo.</u>	<u>24 Mo.</u>
103	10.8	11.0	13.1	12.7	11.7
105	13.7	12.9	14.4	15.3	17.1
106	23.6	16.2	16.7	16.3	17.0
108	6.5	7.7	11.1	10.9	14.6
112	9.2	12.7	14.9	13.5	13.0
115	34.1	42.2	41.5	35.0	28.3
118	5.6	6.6	7.2	7.3	8.3
120	11.4	8.6	9.5	9.4	11.8
122	21.6	14.3	14.1	14.8	15.9

Start July 9, 1975

<u>Site #</u>	<u>3 Mo.</u>	<u>6 Mo.</u>	<u>12 Mo.</u>	<u>21 Mo.</u>
103	11.1	13.6	13.1	11.8
105	12.0	13.1	15.2	17.3
106	8.7	12.6	14.5	16.1
108	8.8	12.2	12.0	15.7
112	16.2	17.9	14.6	13.6
115	50.3	58.7	35.3	27.4
118	7.6	7.8	7.7	8.7
120	5.8	7.4	8.9	11.9
122	6.9	10.8	13.1	15.1

Table 20 (Continued)

II. SO₂ (ppb)Start Nov. 10, 1974

<u>Site #</u>	<u>3 Mo.</u>	<u>6 Mo.</u>	<u>12 Mo</u>	<u>24 Mo.</u>	<u>30 Mo.</u>
103	32.6	22.0	15.5	13.0	12.4
105	14.5	15.1	12.7	13.3	13.4
106	31.7	39.1	28.4	21.2	20.3
108	44.9	40.3	23.8	17.9	17.3
112	n.d.	n.d.	n.d.	n.d.	n.d.
115	46.6	45.4	35.2	25.9	23.1
118	n.d.	n.d.	n.d.	n.d.	n.d.
120	8.7	9.8	7.0	7.5	7.9
122	42.7	38.4	23.9	16.8	15.5

n.d. - not determined.

Start Jan. 15, 1975

<u>Site #</u>	<u>3 Mo.</u>	<u>6 Mo.</u>	<u>12 Mo.</u>	<u>24 Mo.</u>
103	11.4	10.0	10.6	10.3
105	15.7	13.2	11.8	13.5
106	46.5	35.1	23.8	19.8
108	35.6	21.0	16.1	14.3
112	n.d.	n.d.	n.d.	n.d.
115	44.1	32.8	34.7	21.8
118	n.d.	n.d.	n.d.	n.d.
120	8.8	7.1	6.8	7.7
122	34.0	23.4	16.2	12.9

Table 20 (Continued)

Start April 15, 1975

<u>Site #</u>	<u>3 Mo.</u>	<u>6 Mo.</u>	<u>12 Mo</u>	<u>15 Mo.</u>	<u>24 Mo.</u>
103	8.5	9.0	10.8	10.4	9.9
105	10.6	10.2	11.1	12.3	13.0
106	23.6	17.6	15.6	15.4	15.6
108	6.3	7.4	10.1	9.9	11.6
112	n.d.	n.d.	n.d.	n.d.	n.d.
115	21.4	25.1	25.9	21.9	17.6
118	n.d.	n.d.	n.d.	n.d.	n.d.
120	5.4	5.3	6.8	6.9	7.7
122	12.7	9.4	10.4	10.0	9.7

Start July 9, 1975

<u>Site #</u>	<u>3 Mo.</u>	<u>6 Mo.</u>	<u>12 Mo.</u>	<u>21 Mo.</u>
103	9.5	11.3	10.9	10.1
105	9.8	10.5	12.7	13.4
106	11.6	12.6	13.3	14.5
108	8.5	11.3	10.8	12.3
112	n.d.	n.d.	n.d.	n.d.
115	28.8	36.7	22.0	17.0
118	n.d.	n.d.	n.d.	n.d.
120	5.2	6.5	7.3	8.0
122	6.0	9.1	9.4	9.3

Table 20 (Continued)

III. H₂S (ppb)

Start Nov. 10, 1974

<u>Site #</u>	<u>3 Mo.</u>	<u>6 Mo.</u>	<u>12 Mo</u>	<u>24 Mo.</u>	<u>30 Mo.</u>
103	2.5	2.9	5.1	4.8	4.4
105	7.4	10.1	11.0	8.8	7.7
106	2.5	2.5	3.7	4.7	4.3
108	2.5	8.2	6.4	5.3	4.9
112	n.d.	n.d.	n.d.	n.d.	n.d.
115	2.5	2.5	41.8	42.4	34.4
118	n.d.	n.d.	n.d.	n.d.	n.d.
120	2.6	2.7	4.4	7.0	7.6
122	2.5	2.5	3.7	5.5	4.8

n.d - not determined.

Start Jan. 15, 1975

<u>Site #</u>	<u>3 Mo.</u>	<u>6 Mo.</u>	<u>12 Mo.</u>	<u>24 Mo.</u>
103	3.2	3.3	5.9	4.9
105	12.8	13.5	11.1	8.3
106	-	5.5	6.9	5.0
108	13.8	10.2	7.0	5.5
112	n.d.	n.d.	n.d.	n.d.
115	-	2.9	83.0	43.2
118	n.d.	n.d.	n.d.	n.d.
120	2.8	2.8	6.9	7.9
122	-	5.1	4.0	5.5

Table 20 (Continued)

Start April 15, 1975

<u>Site #</u>	<u>3 Mo.</u>	<u>6 Mo.</u>	<u>12 Mo</u>	<u>15 Mo.</u>	<u>24 Mo.</u>
103	3.3	7.3	6.0	6.0	4.8
105	14.2	11.9	9.7	9.5	7.0
106	5.5	4.9	6.7	6.1	4.7
108	6.6	4.6	4.4	4.1	4.1
112	n.d.	n.d.	n.d.	n.d.	n.d.
115	2.9	61.4	67.9	57.1	38.4
118	n.d.	n.d.	n.d.	n.d.	n.d.
120	2.8	6.0	8.5	8.4	8.8
122	5.1	4.4	4.9	6.7	5.1

Start July 9, 1975

<u>Site #</u>	<u>3 Mo.</u>	<u>6 Mo.</u>	<u>12 Mo.</u>	<u>21 Mo.</u>
103	11.2	8.6	6.7	5.0
105	9.6	8.7	8.3	6.0
106	4.3	7.7	6.2	4.6
108	2.6	3.8	3.5	3.7
112	n.d.	n.d.	n.d.	n.d.
115	120	123	70.7	43.5
118	n.d.	n.d.	n.d.	n.d.
120	9.2	11.0	9.8	9.7
122	3.6	3.5	7.1	5.1

Table 20 (Continued)

IV. Ozone (ppb)

Start Nov. 10, 1974

<u>Site #</u>	<u>3 Mo.</u>	<u>6 Mo.</u>	<u>12 Mo</u>	<u>24 Mo.</u>	<u>30 Mo.</u>
103	7.1	13.2	20.1	23.2	22.5
105	7.8	12.0	20.4	22.7	20.8
106	6.6	11.3	21.6	23.4	21.6
108	9.5	15.6	22.7	25.9	24.5
112	7.6	12.6	21.1	23.0	21.6
115	12.5	18.5	26.8	30.5	28.8
118	17.0	21.9	35.0	36.6	34.2
120	9.2	15.4	26.0	27.1	25.2
122	15.7	24.2	33.3	35.3	33.3

Start Jan. 15, 1975

<u>Site #</u>	<u>3 Mo.</u>	<u>6 Mo.</u>	<u>12 Mo.</u>	<u>24 Mo.</u>
103	19.2	26.6	21.4	24.8
105	16.3	24.4	21.2	24.0
106	16.0	26.0	23.3	23.6
108	21.6	28.2	25.3	26.4
112	17.7	25.2	22.2	23.4
115	24.5	29.8	28.6	34.5
118	26.8	41.0	36.5	38.5
120	21.5	30.4	27.2	27.5
122	32.8	40.0	34.7	35.7

Table 20 (Continued)

Start April 15, 1975

<u>Site #</u>	<u>3 Mo.</u>	<u>6 Mo.</u>	<u>12 Mo</u>	<u>15 Mo.</u>	<u>24 Mo.</u>
103	34.1	27.1	22.1	24.8	24.9
105	32.4	28.8	21.8	24.6	23.0
106	36.0	32.0	24.2	26.0	24.2
108	34.9	29.8	25.4	27.8	26.7
112	32.7	29.6	23.0	25.2	23.8
115	35.1	35.0	29.0	31.6	31.4
118	55.3	48.0	37.2	39.4	37.3
120	39.2	36.5	27.1	29.4	27.7
122	47.3	42.4	35.2	37.7	35.6

Start July 9, 1975

<u>Site #</u>	<u>3 Mo.</u>	<u>6 Mo.</u>	<u>12 Mo.</u>	<u>21 Mo.</u>
103	20.1	16.0	22.5	23.6
105	25.1	18.0	22.6	21.7
106	27.9	20.6	23.5	22.5
108	24.8	22.4	26.0	25.5
112	26.4	19.3	23.4	22.6
115	34.9	27.4	30.8	30.9
118	40.8	32.0	35.4	34.8
120	33.9	24.1	27.0	26.1
122	37.5	29.4	35.3	33.9

Table 20 (Continued)

V. NOX (ppb)

Start Nov. 10, 1974

<u>Site #</u>	<u>3 Mo.</u>	<u>6 Mo.</u>	<u>12 Mo</u>	<u>24 Mo.</u>	<u>30 Mo.</u>
103	41.3	31.0	31.3	38.9	40.6
105	49.8	52.1	46.4	47.6	49.7
106	40.3	45.5	42.9	49.7	51.2
108	36.5	34.1	31.9	35.0	36.3
112	44.0	43.8	46.4	48.4	43.8
115	20.4	18.0	16.9	17.4	18.6
118	41.7	17.0	14.6	14.7	15.7
120	35.4	33.8	31.5	32.4	34.1
122	10.7	9.6	8.6	10.4	10.5

Start Jan. 15, 1975

<u>Site #</u>	<u>3 Mo.</u>	<u>6 Mo.</u>	<u>12 Mo.</u>	<u>24 Mo.</u>
103	20.8	25.4	32.0	40.5
105	54.4	46.4	46.4	49.7
106	50.7	41.3	53.9	53.6
108	31.7	28.3	32.5	36.4
112	43.5	39.4	50.0	50.5
115	15.5	14.0	17.4	18.3
118	19.4	14.8	15.0	16.0
120	32.3	31.8	31.5	34.1
122	8.4	7.2	9.8	10.6

Table 20 (Continued)

Start April 15, 1975

<u>Site #</u>	<u>3 Mo.</u>	<u>6 Mo.</u>	<u>12 Mo</u>	<u>15 Mo.</u>	<u>24 Mo.</u>
103	30.1	31.5	38.0	38.0	43.0
105	38.3	40.7	45.8	45.3	49.1
106	32.0	40.3	53.2	51.1	52.6
108	24.9	29.7	34.4	33.8	36.8
112	35.4	49.0	51.5	49.6	50.6
115	12.5	15.8	17.6	17.1	18.8
118	10.3	12.2	13.5	13.5	15.4
120	31.2	29.2	31.6	31.3	34.2
122	6.1	7.6	10.5	9.9	10.7

Start July 9, 1975

<u>Site #</u>	<u>3 Mo.</u>	<u>6 Mo.</u>	<u>12 Mo.</u>	<u>21 Mo.</u>
103	32.9	38.6	40.0	44.8
105	43.1	46.3	47.0	50.6
106	48.6	66.5	55.9	55.6
108	34.5	36.6	36.0	38.5
112	62.5	60.4	53.1	52.8
115	19.1	20.8	18.2	19.7
118	14.1	15.0	14.3	16.1
120	27.2	31.2	31.2	34.6
122	9.0	12.3	10.8	11.4

Table 20 (Continued)

VI. THC (ppm)

Start Nov. 10, 1974

<u>Site #</u>	<u>3 Mo.</u>	<u>6 Mo.</u>	<u>12 Mo</u>	<u>24 Mo.</u>	<u>30 Mo.</u>
103	1.56	1.61	1.84	1.94	1.93
105	2.29	2.33	2.27	2.26	2.28
106	1.84	1.83	1.93	2.07	2.10
108	1.93	1.88	1.90	1.99	2.00
112	1.76	1.70	1.71	1.83	1.90
115	1.41	1.41	1.48	1.57	1.63
118	1.38	1.34	1.38	1.52	1.59
120	1.72	1.70	1.82	1.86	1.89
122	1.74	1.72	1.68	1.73	1.72

Start Jan. 15, 1975

<u>Site #</u>	<u>3 Mo.</u>	<u>6 Mo.</u>	<u>12 Mo.</u>	<u>24 Mo.</u>
103	1.66	1.80	1.93	1.96
105	2.37	2.27	2.27	2.27
106	1.82	1.84	2.04	2.14
108	1.84	1.86	1.97	2.01
112	1.64	1.59	1.72	1.89
115	1.41	1.41	1.54	1.64
118	1.29	1.30	1.46	1.60
120	1.69	1.76	1.84	1.88
122	1.71	1.68	1.68	1.73

Table 20 (Continued)

Start April 15, 1975

<u>Site #</u>	<u>3 Mo.</u>	<u>6 Mo.</u>	<u>12 Mo</u>	<u>15 Mo.</u>	<u>24 Mo.</u>
103	1.95	2.08	2.03	2.01	2.01
105	2.17	2.21	2.21	2.20	2.26
106	1.86	2.03	2.13	2.12	2.17
108	1.87	1.92	2.02	2.00	2.02
112	1.54	1.72	1.77	1.80	1.95
115	1.41	1.56	1.58	1.59	1.68
118	1.32	1.42	1.53	1.56	1.66
120	1.84	1.94	1.86	1.87	1.94
122	1.64	1.64	1.72	1.72	1.72

Start July 9, 1975

<u>Site #</u>	<u>3 Mo.</u>	<u>6 Mo.</u>	<u>12 Mo.</u>	<u>21 Mo.</u>
103	2.20	2.06	2.03	2.02
105	2.25	2.27	2.20	2.28
106	2.20	2.24	2.19	2.21
108	1.98	2.08	2.04	2.04
112	1.89	1.86	1.87	2.01
115	1.70	1.66	1.63	1.72
118	1.51	1.62	1.62	1.70
120	2.04	1.92	1.88	1.95
122	1.63	1.68	1.74	1.74

Table 21a. Weighted Averages for Total Suspended
Particulates ($\mu\text{g}/\text{m}^3$)

I. Start Nov. 10, 1974

<u>Site #</u>	<u>3 Mo.</u>	<u>6 Mo.</u>	<u>12 Mo.</u>	<u>18 Mo.</u>	<u>24 Mo.</u>	<u>30 Mo.</u>
103	n.d.	90.7	105.2	102.4	101.3	96.5
105		80.5	91.4	88.9	88.6	87.5
106		87.6	90.3	83.9	80.8	79.1
108		59.4	81.6	87.2	89.8	86.6
112		70.2	89.3	92.9	85.8	80.4
115		44.3	65.3	64.0	60.5	58.7
118		55.5	85.6	74.2	72.6	68.1
120		63.6	84.7	79.6	66.3	63.6
122		34.8	57.8	56.1	55.5	54.2

n.d. - not determined.

II. Start Jan. 15, 1975

<u>Site #</u>	<u>3 Mo.</u>	<u>6 Mo.</u>	<u>12 Mo.</u>	<u>24 Mo.</u>
103	90.7	105.2	98.8	96.8
105	80.5	91.4	85.4	81.4
106	87.6	90.4	78.7	78.6
108	59.4	81.6	81.1	83.4
112	70.2	89.3	82.1	79.2
115	44.3	65.2	58.7	58.6
118	55.5	85.6	69.6	65.3
120	63.6	84.7	71.8	64.9
122	34.8	57.8	51.8	53.5

Table 21a (Continued)

III. Start April 15, 1975

<u>Site #</u>	<u>3 Mo.</u>	<u>6 Mo.</u>	<u>12 Mo</u>	<u>15 Mo.</u>	<u>24 Mo.</u>
103	107.8	103.1	96.1	95.8	95.2
105	97.4	90.8	86.1	86.2	87.7
106	91.5	83.2	76.4	77.1	77.6
108	92.2	93.2	83.5	86.7	86.8
112	98.4	97.5	80.6	80.5	78.5
115	72.6	66.7	55.4	57.1	57.7
118	93.4	76.5	64.5	71.4	67.1
120	95.2	82.8	65.3	62.9	60.3
122	68.3	60.7	51.5	54.1	54.8

IV. Start July 9, 1975

<u>Site #</u>	<u>3 Mo.</u>	<u>6 Mo.</u>	<u>12 Mo.</u>	<u>21 Mo.</u>
103	100.5	92.4	93.5	93.9
105	86.3	79.3	83.8	87.4
106	76.1	67.0	73.2	76.2
108	94.1	80.6	85.5	86.4
112	96.8	74.9	75.9	75.6
115	62.9	52.2	54.2	56.7
118	61.5	53.5	61.5	60.4
120	74.6	58.8	55.0	55.5
122	54.0	45.7	51.0	53.7

Table 21b. Weighted Averages for Sulfate ($\mu\text{g}/\text{m}^3$)

I. Start Nov. 10, 1974

<u>Site #</u>	<u>3 Mo.</u>	<u>6 Mo.</u>	<u>12 Mo</u>	<u>24 Mo.</u>	<u>30 Mo.</u>
103	n.d.	17.8	14.0	13.9	13.1
105		10.4	13.5	13.3	12.5
106		12.8	15.4	14.0	12.8
108		10.5	15.4	15.0	13.9
112		9.8	14.3	13.4	12.2
115		10.4	14.3	12.9	12.0
118		5.9	11.3	11.7	11.0
120		10.9	16.3	13.6	12.3
122		7.6	13.2	12.4	11.5

n.d. - not determined

II. Start Jan. 15, 1975

<u>Site #</u>	<u>3 Mo.</u>	<u>6 Mo.</u>	<u>12 Mo.</u>	<u>24 Mo.</u>
103	17.8	13.3	13.1	13.3
105	10.4	12.6	12.4	12.6
106	12.8	14.0	13.5	12.7
108	10.5	13.7	14.1	13.9
112	9.8	13.3	13.0	12.4
115	10.4	14.5	12.7	11.8
118	5.9	11.1	10.9	11.2
120	10.9	15.3	14.0	12.2
122	7.6	13.2	12.1	11.8

Table 21b (Continued)

III. Start April 15, 1975

<u>Site #</u>	<u>3 Mo.</u>	<u>6 Mo.</u>	<u>12 Mo</u>	<u>15 Mo.</u>	<u>24 Mo.</u>
103	12.5	13.8	12.3	12.7	12.9
105	13.8	14.2	12.2	12.6	12.4
106	14.5	15.9	13.2	13.2	12.4
108	15.2	16.4	13.8	14.0	13.7
112	14.9	15.2	12.4	12.5	11.9
115	15.9	14.8	12.6	11.9	11.4
118	12.4	12.0	10.8	11.0	11.1
120	17.5	17.4	13.0	12.8	11.6
122	15.7	14.4	11.7	11.7	11.4

IV. Start July 9, 1975

<u>Site #</u>	<u>3 Mo.</u>	<u>6 Mo.</u>	<u>12 Mo.</u>	<u>21 Mo.</u>
103	14.5	12.8	12.5	12.8
105	14.4	12.3	12.2	12.1
106	17.1	13.1	12.5	11.8
108	17.4	14.5	13.7	13.5
112	15.5	12.8	11.9	11.5
115	14.1	11.8	11.2	10.9
118	11.6	10.7	10.6	10.9
120	17.3	12.6	11.3	10.6
122	13.3	10.9	10.8	10.8

Table 21c. Weighted Averages for Nitrate ($\mu\text{g}/\text{m}^3$)

I. Start Nov. 10, 1974

<u>Site #</u>	<u>3 Mo.</u>	<u>6 Mo.</u>	<u>12 Mo</u>	<u>24 Mo.</u>	<u>30 Mo.</u>
103	n.d	8.6	5.6	4.8	4.6
105		5.6	4.7	4.4	4.3
106		6.4	4.7	4.2	4.1
108		5.7	4.7	4.3	4.2
112		5.4	4.3	3.9	3.8
115		4.1	3.4	3.5	3.6
118		2.8	2.6	2.9	3.0
120		5.7	4.9	4.1	4.0
122		4.9	3.7	3.8	3.9

n.d - not determined

II. Start Jan. 15, 1975

<u>Site #</u>	<u>3 Mo.</u>	<u>6 Mo.</u>	<u>12 Mo.</u>	<u>24 Mo.</u>
103	8.6	3.4	3.5	3.8
105	5.6	4.7	4.2	4.1
106	6.4	4.1	3.8	3.7
108	5.7	4.1	4.1	4.0
112	5.4	3.8	3.7	3.6
115	4.1	2.9	3.1	3.3
118	2.8	2.6	2.7	2.9
120	5.7	5.1	4.4	3.8
122	4.9	3.5	3.3	3.5

Table 21c (Continued)

III. Start April 15, 1975

<u>Site #</u>	<u>3 Mo.</u>	<u>6 Mo.</u>	<u>12 Mo</u>	<u>15 Mo.</u>	<u>24 Mo.</u>
103	2.5	2.9	3.5	3.5	3.7
105	4.2	3.7	4.1	4.0	4.0
106	3.2	3.0	3.6	3.6	3.5
108	3.3	3.6	3.9	3.8	3.8
112	3.0	3.1	3.5	3.4	3.4
115	2.5	2.6	3.8	3.6	3.5
118	2.5	2.3	3.0	2.8	3.1
120	4.8	4.1	4.0	3.7	3.6
122	2.8	2.5	3.3	3.2	3.3

IV. Start July 9, 1975

<u>Site #</u>	<u>3 Mo.</u>	<u>6 Mo.</u>	<u>12 Mo.</u>	<u>21 Mo.</u>
103	3.1	3.6	3.7	3.8
105	3.3	3.7	3.9	4.0
106	2.8	3.2	3.5	3.5
108	3.9	4.0	3.9	3.9
112	3.2	3.5	3.6	3.5
115	2.7	3.2	3.4	3.4
118	2.2	2.8	2.9	3.1
120	3.7	3.7	3.7	3.6
122	2.2	3.0	3.4	3.6

Table 22a. Results of Regression Analysis for Galvanized Steel

<u>Regression</u> <u>No.</u>	<u>log k</u>	<u>n</u>	<u>TS</u>	<u>SO₂</u>	<u>H₂S</u>	<u>O₃</u>	<u>NO_x</u>	<u>TSP</u>	<u>SO₄</u>	<u>NO₃</u>	<u>F</u>	<u>R²</u>	<u>S</u>
1. First Set													
1	1.977	0.144									F _{1,22} = 16.885	0.4342	0.0471
2	1.845	0.103								+0.018	F _{2,21} = 10.477	0.4994	0.0454
3	1.589	0.011	+0.002							+0.037	F _{3,20} = 12.730	0.6563	0.0385
4	1.568	0.048	+0.003					+0.001		+0.024	F _{4,19} = 13.416	0.7385	0.0345
5	1.586	0.042	+0.003					+0.002	-0.004	+0.026	F _{5,18} = 10.643	0.7473	0.0348
6	1.557	0.045	+0.003		+0.004			+0.001	-0.002	+0.028	F _{6,17} = 9.269	0.7659	0.0345
7	1.552	0.050	+0.005	-0.002	+0.003			+0.001	-0.002	+0.028	F _{7,16} = 7.610	0.7690	0.0353
8	1.477	0.086	+0.002	-0.002	+0.005	+0.004		+0.002	-0.007	+0.036	F _{8,15} = 6.868	0.7855	0.0352
9	1.431	0.091	+0.002	+0.002	+0.005	+0.005	+0.001	+0.002	-0.007	+0.039	F _{9,14} = 5.740	0.7868	0.0363

(k in $\mu\text{g}/\text{cm}^2 \text{ month}$)

Table 22a (Continued)

<u>Regression</u> <u>No.</u>	<u>log k</u>	<u>n</u>	<u>TS</u>	<u>SO₂</u>	<u>H₂S</u>	<u>O₃</u>	<u>NO_x</u>	<u>TSP</u>	<u>SO₄</u>	<u>NO₃</u>	<u>F</u>	<u>R²</u>	<u>S</u>
2. 2nd Set													
1	1.954	0.178									F _{1,23} = 28.198	0.5508	0.0528
2	1.670	0.101	+0.004	-0.004	+0.004		-0.002	+0.003	-0.013	+0.030	F _{8,16} = 9.956	0.8327	0.0386
3	1.863	0.102	+0.004	-0.005	+0.005	-0.005	-0.002	+0.003	-0.013	+0.030	F _{9,15} = 9.969	0.8568	0.0369
3. Fourth Set													
1	1.766	0.080									F _{1,26} = 4.154	0.1383	0.0695
2	1.911	0.184	-0.005	+0.013	-0.011		-0.004	+0.002	-0.022	+0.070	F _{8,19} = 7.959	0.7702	0.0420
3	1.953	0.174	-0.005	+0.012	-0.011	-0.001	-0.005	+0.002	-0.020	+0.063	F _{9,18} = 6.734	0.7710	0.0430

Table 22b. Results of Regression Analysis for Weathering Steel

Regression No.	$\log k$	n	$\overline{TS}$	$\overline{SO_2}$	$\overline{H_2S}$	$\overline{O_3}$	$\overline{NO_x}$	$\overline{TSP}$	$\overline{SO_4}$	$\overline{NO_3}$	$\overline{F}$	$\overline{R^2}$	$\overline{S}$
1. First Set													
1	0.822	0.545									$F_{1,22} = 75.879$	0.7752	0.0839
2	0.687	0.494	+0.003								$F_{2,21} = 44.207$	0.8081	0.0794
3	0.343	0.542	+0.004						+0.024		$F_{3,20} = 48.575$	0.8793	0.0645
4	0.328	0.500	+0.005					+0.0005	+0.022		$F_{4,19} = 34.987$	0.8805	0.0658
5	0.325	0.496	+0.005					+0.0005	+0.022	+0.001	$F_{5,18} = 26.521$	0.8805	0.0676
6	0.322	0.490	+0.005		-0.008			+0.001	+0.020	-0.003	$F_{6,17} = 23.224$	0.8913	0.0664
7	0.365	0.503	+0.008	-0.004	-0.009			+0.001	+0.020	-0.003	$F_{7,16} = 19.270$	0.8940	0.0576
8	0.722	0.568	-0.004	+0.006	+0.001		-0.010	+0.006	-0.005	-0.001	$F_{8,15} = 85.555$	0.9786	0.0314
9	0.522	0.618	-0.005	+0.009	+0.010	+0.005	-0.009	+0.006	-0.008	+0.009	$F_{9,14} = 75.472$	0.9798	0.0315

(k in g cm⁻² hr⁻¹)

Table 22b (Continued)

<u>Regression</u> <u>No.</u>	<u>log k</u>	<u>n</u>	<u>IS</u>	<u>SO₂</u>	<u>H₂S</u>	<u>O₃</u>	<u>NO_x</u>	<u>TSP</u>	<u>SO₄</u>	<u>NO₃</u>	<u>F</u>	<u>R²</u>	<u>S</u>
<u>2. Second Set</u>													
1	0.775	0.510									$F_{1,23} = 95.467$	0.8058	0.0823
2	0.648	0.493	-0.004	+0.007	+0.007		-0.006	+0.003	+0.004	-0.016	$F_{8,16} = 31.049$	0.9395	0.0551
3	0.832	0.495	-0.004	+0.006	+0.008	-0.005	-0.007	+0.003	+0.009	-0.027	$F_{9,15} = 27.775$	0.9434	0.0550
<u>3. Fourth Set</u>													
1	0.913	0.646									$F_{1,26} = 327.688$	0.9265	0.0635
2	0.898	0.647	+0.001								$F_{2,25} = 163.604$	0.9290	0.0637
3	0.786	0.626	+0.001						+0.007		$F_{3,24} = 107.559$	0.9308	0.0642
4	0.719	0.576	-0.009	+0.016	-0.001		-0.005	+0.001	+0.013	-0.001	$F_{8,19} = 68.735$	0.9666	0.0501
5	0.874	0.540	-0.006	+0.012	-0.001	-0.004	-0.005	+0.002	+0.020	-0.027	$F_{9,18} = 60.030$	0.9678	0.0506

Table 22c. Results of Regression Analysis for House Paint

Regression No.	log k	n	IS	SO ₂	H ₂ S	O ₃	NO _x	TSP	SO ₄	NO ₃	F	R ²	S
i. Latex, North													
1.	1.678									-0.040	F _{1,22} = 9.988	0.3122	0.0671
2	1.750							-0.002		-0.031	F _{2,21} = 8.102	0.4355	0.0623
3	1.561							-0.004	+0.026	-0.032	F _{3,20} = 17.139	0.7200	0.0449
4	1.525		+0.001					-0.003	+0.026	-0.033	F _{4,19} = 12.574	0.7258	0.0456
5	1.535	0.006	+0.001					-0.003	+0.016	-0.034	F _{5,18} = 9.536	0.7259	0.0469
6	1.540	0.003	-0.001	+0.001				-0.003	+0.026	-0.034	F _{6,17} = 7.518	0.7265	0.0482
7	1.538	0.003	-0.002	+0.001	+0.002			-0.003	+0.026	-0.034	F _{7,16} = 6.074	0.7266	0.0496
8	1.279	0.124	-0.010	+0.012	+0.008	+0.014		-0.001	+0.008	-0.005	F _{8,15} = 10.215	0.8449	0.0386
9	1.445	0.103	-0.009	+0.011	+0.010	+0.010	-0.002	-0.001	+0.008	-0.014	F _{9,14} = 9.140	0.8546	0.0387

(k in g/cm² month)

Table 22c (Continued)

Regression No.	log k	n	IS	SO ₂	H ₂ S	O ₃	NO _x	TSP	SO ₄	NO ₃	F	R ²	S
2. Latex, South													
1	1.800									-0.047	F _{1,22} = 9.939	0.3112	0.0783
2	1.548								+0.024	-0.059	F _{2,21} = 15.538	0.5974	0.0613
3	1.524							-0.002	+0.036	-0.051	F _{3,20} = 16.550	0.7126	0.0531
4	1.427	0.069						-0.003	+0.034	-0.037	F _{4,19} = 12.842	0.7300	0.0528
5	1.294	0.104	+0.001					-0.002	+0.034	-0.032	F _{5,18} = 10.811	0.7502	0.0522
6	1.352	0.110	+0.001		-0.007			-0.002	+0.032	-0.036	F _{6,17} = 18.275	0.7839	0.0499
7	1.340	0.098	+0.004	-0.004	-0.008			-0.002	+0.032	-0.035	F _{7,16} = 8.679	0.7915	0.0505
8	0.989	0.067	-0.009	+0.012	+0.002	+0.019		+0.001	+0.008	+0.004	F _{8,15} = 36.824	0.9515	0.0252
9	1.191	0.042	-0.008	+0.010	+0.004	+0.014	-0.003	+0.002	+0.008	-0.008	F _{9,14} = 39.475	0.9624	0.0230

Table 22c (Continued)

<u>Regression</u> <u>No.</u>	<u>log k</u>	<u>n</u>	<u>TS</u>	<u>SO₂</u>	<u>H₂S</u>	<u>O₃</u>	<u>NO_x</u>	<u>TSP</u>	<u>SO₄</u>	<u>NO₃</u>	<u>F</u>	<u>R²</u>	<u>S</u>
3. <u>Oil, North</u>													
1	1.234	0.163							+0.026		F _{2,21} = 8.415	0.4449	0.0744
2	1.274	0.502	+0.002	-0.002	+0.001	+0.015		+0.004	+0.018	-0.033	F _{8,15} = 10.815	0.8522	0.0454
3	1.376	0.490	+0.002	-0.003	+0.002	+0.012	-0.001	+0.004	+0.013	-0.039	F _{9,14} = 9.153	0.8547	0.0466
4. <u>Oil, South</u>													
1	1.263	0.098							+0.021		F _{2,41} = 5.346	0.3374	0.0699
2	1.415	0.451	+0.002	-0.003	+0.003	+0.012		+0.004	+0.011	-0.044	F _{8,15} = 9.783	0.8392	0.0408
3	1.524	0.438	+0.002	-0.004	+0.005	+0.009	-0.002	+0.005	+0.012	-0.050	F _{9,15} = 8.358	0.8431	0.0417

Table 22d. Results of Regression Analysis for Marble

<u>Regression</u> <u>No.</u>	<u>log k</u>	<u>n</u>	<u>TS</u>	<u>SO₂</u>	<u>H₂S</u>	<u>O₃</u>	<u>NO_x</u>	<u>TSP</u>	<u>SO₄</u>	<u>NO₃</u>	<u>F</u>	<u>R²</u>	<u>S</u>
1	2.709	0.306									$F_{1,22} = 75.434$	0.7742	0.0473
2	2.946	0.381								-0.032	$F_{2,21} = 63.459$	0.8580	0.0384
3	2.984	0.422						+0.001		-0.044	$F_{3,20} = 46.141$	0.8738	0.0371
4	2.807	0.507	-0.005	+0.006	+0.004	+0.010		+0.003	-0.013	-0.025	$F_{8,15} = 23.151$	0.9251	0.0330
5	2.900	0.496	-0.005	+0.005	+0.002	+0.007	-0.001	+0.003	-0.013	-0.030	$F_{9,14} = 19.771$	0.9271	0.0337

(k in $\mu\text{g}/\text{cm}^2 \text{ month}$)

Table 23. Test of Hypothesis that Regression Coefficient is Zero

	log	TS	SO ₂	H ₂ S	O ₃	NO _x	TSP	SO ₄	NO ₃
Galvanized Steel (1)	**	-	-	*	*	-	***	*	***
Weathering Steel (1)	****	**	****	****	*	****	****	**	-
Galvanized Steel (2)	****	**	**	**	**	****	****	*	**
Weathering Steel (2)	****	*	*	**	*	****	**	-	*
Galvanized Steel (4)	****	-	*	****	-	****	****	**	*
Weathering Steel (4)	****	*	*	-	*	****	-	*	-
Latex, North	**	****	****	***	**	*	*	*	*
Latex, South	*	****	****	**	****	***	****	***	*
Oil, North	****	-	-	-	**	-	****	***	***
Oil, South	****	-	*	*	**	-	****	*	***
Marble	****	**	*	-	**	-	****	***	***

- Cannot reject at 50%

* Reject at 50%

** Reject at 75%

*** Reject at 90%

**** Reject at 95%

Table 24. Overall Ranking of Test Sites According to Corrosion Data

Site #	Galv. Steel			Weath. Steel			House Paint			Marble	Silver 1st 2nd Year	Al Alloys			
	1st	2nd	3rd 4th	1st	2nd	3rd 4th	LN	LS	ON OS			25 KSI	15 KSI	45 KSI	25 KSI
103	4	2	1 4	3	2	4 4	9	6	2 2	6	4 7	2	5	1	4
105	2	1	5 5	9	9	9 9	7	8	2 1	4	2 6	1	3	5	1
106	6	9	8 8	6	6	6 6	6	7	9 9	9	6 8	4	6	6	9
108	1	2	3 2	2	1	2 2	4	3	5 3	2	3 1	4	4	4	2
112	7	6	7 8	7	6	7 8	7	9	8 8	7	8 9	8	6	8	7
115	5	5	4 6	3	4	3 3	3	2	6 7	5	1 2	9	2	8	8
118	8	6	6 2	5	5	5 4	1	4	2 5	3	9 5	6	8	3	3
120	9	8	9 7	3	8	8 6	4	5	6 6	8	7 4	7	9	2	5
122	3	4	2 1	1	2	1 1	2	1	1 4	1	5 3	3	1	7	6

Table 25. Overall Ranking of Test Sites According to Pollutant Concentrations

Site #	SO ₂	TS	H ₂ S	O ₃	NO _x	THC	TSP	SO ₄	NO ₃
102	3 4	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4
103	6 6 5 5	6 7 8 8	6 7 5 5	6 6 6 6	4 4 4 4	4 4 4 4	1 1 1 1	2 2 2 2	1 3 3 3
105	5 4 3 3	5 5 2 2	2 2 3 3	9 7 9 9	2 3 3 3	2 1 1 1	2 3 2 2	4 4 3 3	2 1 1 1
106	2 2 2 2	3 2 3 3	7 6 6 6	7 8 7 8	1 1 1 1	3 2 2 2	5 5 5 4	3 3 3 4	4 5 5 6
108	3 3 4 4	4 4 5 4	4 4 7 7	5 5 5 5	5 5 5 5	1 3 3 3	3 2 3 3	1 1 1 1	3 2 2 2
112	X X X X	6 6 6 6	X X X X	7 9 8 7	3 2 2 2	5 5 5 5	4 4 4 5	6 5 5 5	7 6 7 8
115	1 1 1 1	1 1 1 1	1 1 1 1	3 3 3 3	7 7 7 7	8 8 8 8	8 8 8 7	7 7 7 6	8 5 5 6
118	X X X X	9 9 9 9	X X X X	1 1 1 1	8 8 8 8	9 9 9 9	6 6 6 6	9 9 9 6	9 9 9 9
120	7 7 7 7	8 8 7 7	3 3 2 2	4 4 4 4	6 5 6 6	6 6 6 6	7 7 7 8	5 6 6 9	5 3 4 4
122	4 5 6 6	2 3 4 5	5 4 4 4	2 2 2 2	9 9 9 9	7 7 7 7	9 9 9 9	8 7 7 8	6 7 8 4

Note: 1 = Start 11-10-74

2 = Start 1-15-75

3 = Start 4-15-75

4 = Start 7-9-75

APPENDIX A
ADDITIONAL EXPOSURE TESTS

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APPENDIX A

ADDITIONAL EXPOSURE TESTS

A. ALUMINUM ALLOY SHEET EXPOSED BY ALCOA

At the start of the exposure test in October 1974 ALCOA personnel exposed a number of Al alloys at all nine sites with the objective to evaluate weathering of such materials and to analyze the deposits as an indicator of the pollutants present on the Al tension samples. The test panels were 4 by 6 in. in size and 0.063 in. thick. Five 2014-T6 panels and a single panel of 1160-H14 and 7075-T6 were exposed at each site. A set of 2014-T6 panels was returned for evaluation after 3, 6, 12 and 24 months. The 1160 and 7075 panels were returned after 24 months. After visual examination, panels from sites #103, 108, and 122 were retained for further analysis while the other panels were re-exposed.

The panels which had been exposed for 3 months were analyzed by weight loss, determination of pH, Cl^- , NO_3^- and SO_4^{2-} -content of a hot water leach of the entire panel and metallographic determination of type and depth of attack. For panels exposed for 6 and 12 months only the analysis of the hot water leach was performed. Panels exposed for 24 months were examined by metallographic observation, analysis of the hot water leach and a tensile test of sheet-type tension specimens machined from the corroded panels.

The attempts to determine the weight loss after three months exposure of the 2014 alloy were unsuccessful since a heavy black film was formed on the sample when it was cleaned according to ASTM G1-67. This film could not be removed completely in a HNO_3 -rinse and some samples showed a weight gain. No weight loss data are, therefore, reported.

The results obtained by ALCOA are shown in Tables A1-A4. It was concluded that differences in the depth of attack at the various sites are small and not significant (Table A2). As expected, pure Al panels incurred considerably

less corrosion than Al 2014-T6 and 7075-T6. The rate of corrosion of Al 2014-T6 decreased markedly after the initial three months of exposure. The results of the tensile tests (Table A4) showed no significant reduction in tensile strength as a result of the two year exposure. There was a slight decrease in elongation as a result of notch effects from sites of corrosion. However, even this was considered to be slight and unrelated to the level of airborne pollutants. Comments on the analyses of the hot water leach (Table A1) have been given in the previous report (5).

B. EXPOSURE OF CLIMAT DEVICES

Starting in April 1976 four sets of CLIMAT (Classification of Industrial and Marine Atmospheres) devices were exposed on all nine test sites for a period of 90 days. Al wire (0.9 mm in diameter and 900 mm long) is wound on plastic, Cu or Fe bolts. From the percent weight loss of the Al wire a corrosion index is calculated. From the Al/nylon couple an atmospheric corrosion index (ACI) is derived, the Al/Fe couple gives the marine corrosion index (MCI) and a calculated combination of the Al/Fe and Al/Cu data provides the industrial corrosion index (ICI). Results are shown in Tables A5 and A6, which contain the average weight loss and corrosion indices for the four sets. Periods of no corrosion were not considered in the averages.

H. H. Lawson of ARMCO Steel Corp., Middletown, Ohio, who provided and analyzed the CLIMAT samples, reached the following conclusions:

"Inspection of the tabular data does not indicate any particular trends with respect to the atmospheres at the sites. The significant corrosion rates, where observed, appear to be random excursions, and are scattered between the various couple indices. In general, as might be expected, the fall/winter exposures are somewhat more severe, and the two 'extremity' sites, 118 and 122, appear to be less corrosive than the rest with respect to the CLIMAT devices. Site 120 is probably the next least corrosive site. It is difficult to determine the most severe site due to the inordinate influence of the excursions referred to earlier. However, I would be inclined to call site 105 the most severe, closely followed by 103. Sites 106 and 108 are comparable and

probably the next most severe. Although Site 115 appears to be severe based on the averages shown in Table A6, this results from a single datum point, the remaining indices being quite low. I would rank the sites from severest to mildest as follows:

105, 103, 106, 108, 112, 115, 120, 118, 122

The St. Louis area does not seem to be particularly corrosive - at least not to A1 1100."

It will be noted that failure of 100% of all A1 tension samples at 25 Ksi occurred in the shortest time at site #105 followed by #103, 122, 106 and 108. All A1 2014 samples at 25 Ksi failed only at sites #105 and 108. Failure times of the other samples also seem to be related to the CLIMAT results.

C. ATMOSPHERIC WEATHERING TEST ON BRONZE SAMPLES

This task was conducted by Prof. D. W. Zimmerman, Director of the Center for Archeometry of Washington University, St. Louis, Mo.

Bronze plates were placed on the roofs of five RAMS stations in the greater St. Louis area. The purpose was to observe and measure the rates of corrosion of plates over a period of at least 2 years to provide fundamental and vital data for the University's outdoor bronze monument conservation program. Specific questions to be studied were:

1. Do wrought and cast bronzes corrode at different rates?
2. How does glass-bead peening (which is used to clean the statues) affect the corrosion rate?
3. How does the alloy composition affect the corrosion rate?

Samples

Fourteen samples 2" x 3" x 1/4" were placed on each of the five sites. Seven samples of each of two alloys: 85% Cu, 5% Sn, 5% Zn, 5% Pb; and 89% Cu, 11% Sn, were prepared as follows:

1. Cast -- surface filed
2. Cast -- surface polished
3. Wrought -- surfaced polished
4. Wrought -- no surface treatment
5. Cast -- no surface treatment
6. Cast -- glass-bead peened
7. Wrought -- glass-bead peened

The samples were weighed before being set in place on April 15th and 16th, 1976, at sites #105, 108, 112, 120 and 122.

After one year of exposure, the results were as follows:

1. The primary effect was a darkening/tarnishing. Very little of the basic green corrosion product has formed yet - only a thin green veil over the "untreated" cast plate at site #122.
2. The 85-5-5-5 (Cu, Sn, Pb, Zn) alloy is darkening considerably faster than the 89-11 (Cu, Sn) alloy.
3. The glass bead peened (the technique used for cleaning outdoor bronze monuments) plates show the same or less darkening than unpeened plates.
4. Areas peened a higher pressure (80-100 psi) and with larger bead size (125 μ m) show less tarnishing than lower pressure (4-60 psi) and smaller bead size (75 μ m).
5. The highly polished, wrought plates show the least tarnishing.
6. No systematic differences between the five sites are apparent. The outdoor test needs to be continued for at least another year; other test sites are being evaluated for this program by Prof. Zimmerman.

D. EXPOSURE OF ATMOSPHERIC CORROSION MONITORS (ACM)

The atmospheric corrosion monitor (ACM) described by Mansfeld and Kenkel (1, 2) consists of a Cu/Zn or Cu/steel couple which registers current flow when electrolyte bridges the dissimilar metal plates. The electrolyte might result from condensation of water from the air on corrosion products, from dew or from rain. It has been shown (1-3) that the ACM data not only measure the time-of-wetness of a test panel, but can also determine the

corrosivity of a test site. Three ACMs were installed on October 3, 1975 at Sites #103, 112 and 122; later an additional Cu/steel ACM was installed at site #106. The ACM recording is stored in the RAMS/RAPS system; an evaluation of some of these data is being conducted at the Science Center under an ONR contract (4) which deals with basic mechanisms of atmospheric corrosion.

At present, only time-of-wetness t_w data have been determined from the recorded ACM data as the hours per day during which the ACM signal exceeds the background current which is flowing when the surface is dry. In Fig. A1, ACM data are plotted for four sites in December 1976 as the sum of time-of-wetness as a function of time. It can be seen that there are discontinuities in the increase of t_w which reflect different climatic conditions. Between December 21, 1976 and December 27, 1976 the ACM surface was dry at site #103. At site #106 similar conditions occurred for about the same time period. Surprisingly, the ACM at site #112, which is close to site #106, did not show the absence of condensation, but instead a steep increase of the t_w -hours was recorded. At site #122 no t_w -signal was received between December 20 and December 31, 1976. In the following month 8.0 hours/day was measured as the average t_w at site #122 indicating that the ACM was working properly. In general, temperatures at site #122 were appreciably lower than at the other sites.

Fig. A2 shows the t_w -data obtained between October 1975 and March 1977 for the different test sites. Several maxima and minima occur at similar times for all test sites, although the absolute t_w -values can be quite different for the different test sites. For December 1975 the average values fall between 49% for site #103 and 94% for site #122, which show that for an accurate theoretical evaluation of corrosion behavior in atmospheric exposure tests reliable time-of-wetness data have to be available in order to explain the different corrosion results at various test sites. Average atmospheric data such as daily average RH-values for a general area do not seem to be sufficient to explain the reactions occurring in the microclimate of a test site.

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3. F. Mansfeld, "Atmospheric Corrosion Rates, Time-of-Wetness and Relative Humidity, submitted to *Werkstoffe and Korrosion*.
4. "Electrochemical Studies of Atmospheric Corrosion," F. Mansfeld, Principal Investigator, Contract No. 00014-75-C-0788 with Office of Naval Research.
5. F. Mansfeld, "Study of the Effects of Airborne Sulfur Pollutants on Materials", RAPS, Task Order No. 112, Contract No.-68-02-2093, Two-Year Exposure Report, Rockwell International, AMC 7010T0112AR.

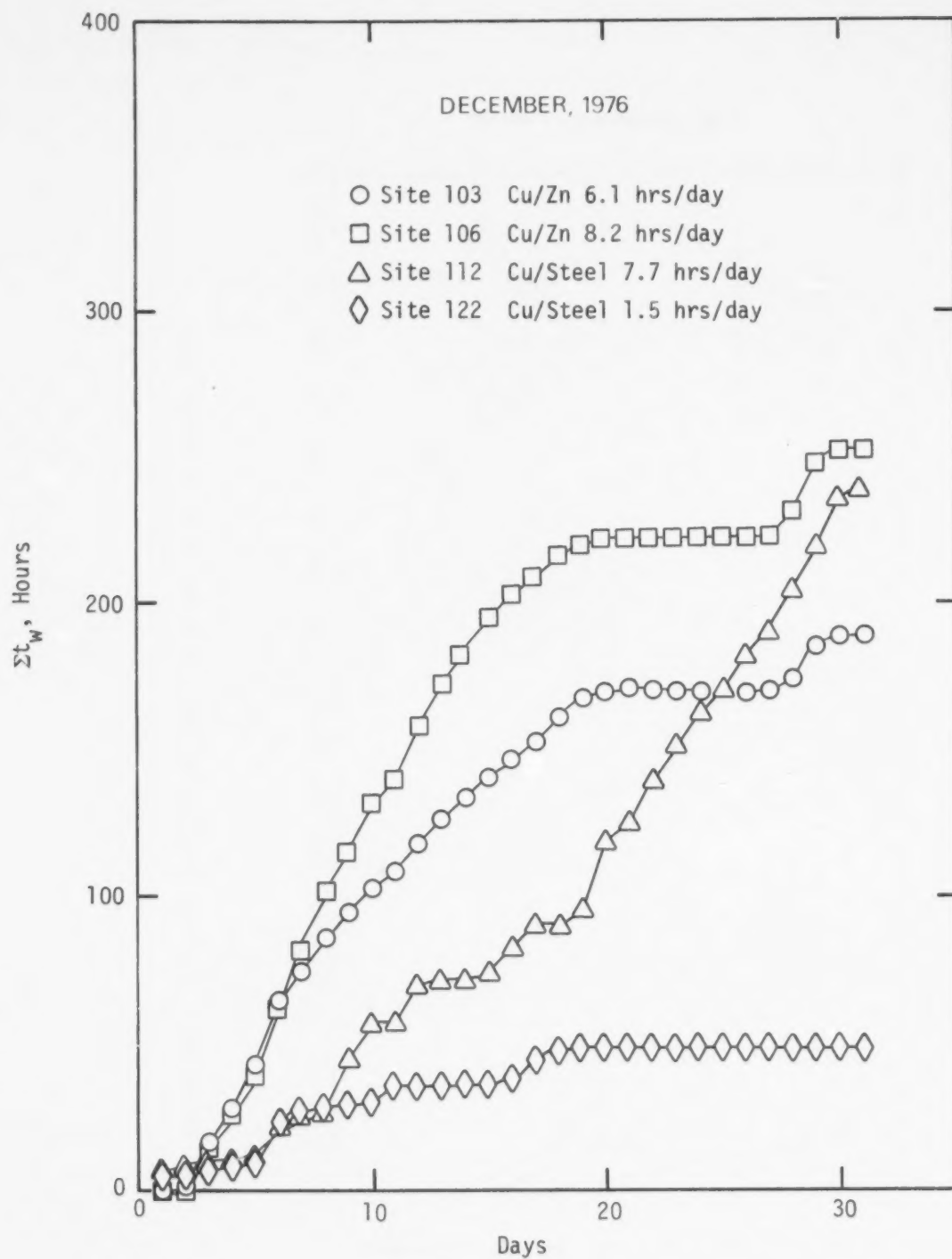


FIGURE A1. ACM DATA, DECEMBER 1976

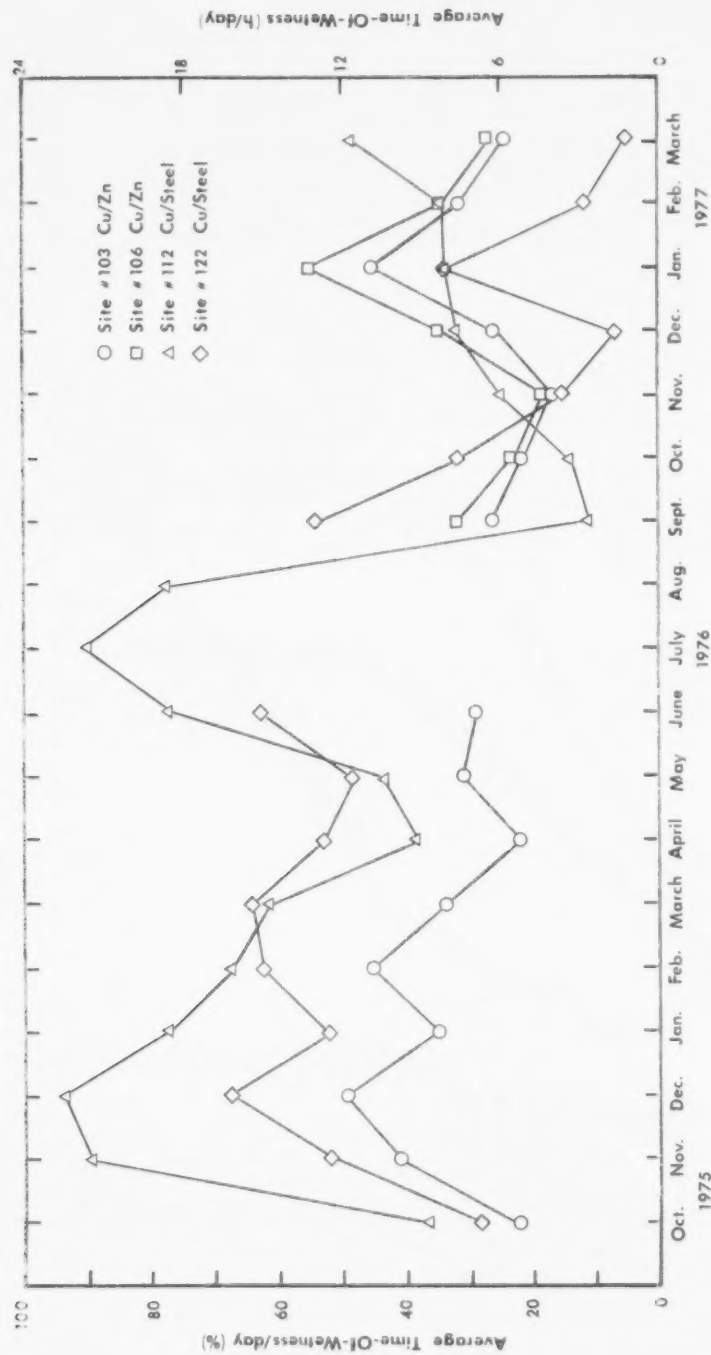


FIGURE A2. t_w -DATA OBTAINED BETWEEN OCTOBER 1975 AND MARCH 1977.

Table A1
Analyses of Hot Water Leach of Aluminum Alloy Sheet Panels Exposed at Nine Sites in St. Louis, Mo.
Surface Area Leached was 310 cm² (48 In²)

Alloy	Exposure Months	Anion	Concentration: mg/mm ² x 10 ⁻⁵											
			Site 103	Site 105	Site 106	Site 108	Site 112	Site 115	Site 118	Site 120	Site 122	pH of Leach		
2014-T6	3	SO ₄	5.92	2.69	1.72	2.69	2.58(+)	1.72	1.72	1.18	1.18			
2014-T6	6	SO ₄	5.49	2.15	1.18	1.94	0.86	1.72	1.94	1.72	1.18			
2014-T6	12	SO ₄	2.26	0.86	1.18	0.86	0.86	0.186	0.65	1.08	<0.16			
2014-T6	24	SO ₄	0.84	-----	-----	0.00	-----	-----	-----	-----	0.65			
7075-T6	24	SO ₄	0.00	-----	-----	0.00	-----	-----	-----	-----	0.00			
1160-H14	24	SO ₄	0.65	-----	-----	0.00	-----	-----	-----	-----	0.00			
2014-T6	3	Cl	0.54(+)	0.42	0.25	0.29	0.27(+)	0.18	0.23	0.25	0.16			
2014-T6	6	Cl	0.81	0.50	0.29	0.29	0.34	0.27	0.19	0.27	0.23			
2014-T6	12	Cl	0.50	0.40	0.29	0.34	0.34	0.29	0.34	0.29	0.19			
2014-T6	24	Cl	0.13	-----	-----	0.17	-----	-----	-----	-----	0.13			
7075-T6	24	Cl	0.17	-----	-----	0.09	-----	-----	-----	-----	0.09			
1160-H14	24	Cl	0.13	-----	-----	0.15	-----	-----	-----	-----	0.13			
2014-T6	3	NO ₃	<0.4(*)	0.22	<0.2(*)	0.43	<0.4(*)	0.32	0.43	0.32	0.22			
2014-T6	6	NO ₃	0.97	0.75	0.65	1.08	0.65	0.75	0.86	0.75	0.75			
2014-T6	12	NO ₃	0.65	0.64	0.43	0.86	0.22	0.43	0.65	0.86	0.22			
2014-T6	24	NO ₃	0.41	-----	-----	0.41	-----	-----	-----	-----	0.17			
7075-T6	24	NO ₃	0.30	-----	-----	0.35	-----	-----	-----	-----	0.17			
1160-H14	24	NO ₃	0.25	-----	-----	0.29	-----	-----	-----	-----	0.23			
2014-T6	3		4.10	4.80	4.90	4.90	4.90	4.90	4.90	5.40	5.10			
2014-T6	6		5.30	4.60	4.70	4.70	4.60	4.60	4.80	4.80	5.00			
2014-T6	12		5.40	5.20	5.40	5.30	5.70	6.70	5.60	5.90	5.60			
2014-T6	24		5.00	-----	-----	5.00	-----	-----	-----	-----	5.20			
7075-T6	24		5.20	-----	-----	5.10	-----	-----	-----	-----	5.30			
1160-H14	24		5.30	-----	-----	5.00	-----	-----	-----	-----	5.30			

Note: (*) Below limit of detection based on area of leached surface.

(+) Surface area leached was only 142 cm² (22 In.²).

TABLE A2
Type and Depth of Corrosion on 2014-T6 Sheet Panels Exposed Three Months
at Nine Sites in St. Louis, MO.

Test Site	Type of Corrosion		Depth of Attack - mm			
	Skyward	Earthward	Skyward	Earthward		
			Max.	Max.	Avg.	
103	P	P	0.0215	0.0576	0.0198	
105	P	P	0.0109	0.0330	0.0250	
106	P + SI	P + SI	0.0122	0.0575	0.0326	
108	P + SI	P + SI	0.0262	0.0429	0.0233	
112	P	P + SI	0.0248	0.0310	0.0132	
115	P + SI	P + SI	0.0244	0.0340	0.0082	
118	P + SI	P + SI	0.0346	0.0179	0.0151	
120	P + SI	P + SI	0.0330	0.0266	0.0185	
122	P + SI	P + SI	0.0573	0.0355	0.0226	
All 9 Sites						
High	--	--	0.0573	0.0576	0.0326	
Avg.	P + SI	P + SI	0.0272	0.0373	0.0198	
Low	--	--	0.0109	0.0179	0.0082	
Range	--	--	0.0464	0.0397	0.0244	

Note: P = Pitting

SI = Slight amount of intergranular attack

TABLE A3

Type and Depth of Corrosion of Aluminum Alloy Sheet
Panels Exposed Two Years in St. Louis, MO.

Alloy	Test Site	Type of Corrosion (1)		Max. Depth of Attack - mm		Max. Depth of Attack - mm	
		Skyward	Earthward	Skyward	Earthward	Skyward	Earthward
1160-H14	103	P	P	0.013	0.010	0.0005	0.0004
	108	NAA	P	-----	0.015	-----	0.0006
	122	P	P	0.003	0.005	0.0001	0.0002
	Avg.	P	P	0.008	0.010	0.0003	0.0004
2014-T6	103	I	I	0.042	0.071	0.0017	0.0028
	108	I	I	0.034	0.058	0.0013	0.0023
	122	I	I	0.033	0.083	0.0013	0.0033
	Avg.	I	I	0.036	0.071	0.0014	0.0028
7075-T6	103	I	I	0.048	0.097	0.0019	0.0038
	108	I	I	0.042	0.052	0.0017	0.0021
	122	P	P	0.024	0.015	0.0009	0.0006
	Avg.	I	I	0.038	0.055	0.0015	0.0022

Note: (1) P = Pitting, I = Intergranular, NAA = No Appreciable Attack

TABLE A4

Tensile Property Data of Aluminum Alloy Sheet Panels
Exposed Two Years in St. Louis, MO.

Alloy	Test Site	Long Transverse Tensile Props. (1)				Elong. %	% Decrease By Corrosion	
		Yield Strength MPa	Yield Strength ksi	Tensile Strength MPa	Tensile Strength ksi		T.S.	El.
1160-H14	Unexposed	105	15.2	113	16.4	10.8	----	----
	103	---	----	113	16.4	11.0	0	0
	108	---	----	112	16.2	10.3	1	5
	122	---	----	112	16.2	11.0	1	0
2014-T6	Unexposed	421	61.0	486	70.5	11.0	----	----
	103	---	----	482	69.9	10.0	1	9
	108	---	----	481	69.8	10.0	1	9
	122	---	----	483	70.1	10.0	1	9
7075-T6	Unexposed	502	72.9	563	81.7	11.0	----	----
	103	---	----	560	81.1	9.7	1	12
	108	---	----	563	81.7	10.0	0	9
	122	---	----	566	82.1	10.0	0	9

Note: (1) 1.63 x 9.53 x 102 mm (0.064 x 0.375 x 4.0 inch) sheet type specimens, original properties in quadruplicate, corroded specimen in triplicate.

TABLE A5
Summary of Climat Results

Site No.	EXPOSURE PERIOD 1976/1977	ATMOSPHERIC (ACI)			MARINE (MCI)			INDUSTRIAL (ICI)		
		Wt. Loss (mg)	%	Rating*	Wt. Loss (mg)	%	Rating	Wt. Loss (mg)	%	Rating
103	April	0.2	0.01	N	5.6	0.4	N	11.0	0.8	N
	July	0	0	N	28.3	2.04	M	4.6	0.32	N
	Oct.	0.6	0.04	N	10.5	0.7	N	13.5	0.87	N
	Jan. April	0	0	N	5.8	0.37	N	11.8	0.75	N
105	April	0.1	0.01	N	1.7	0.12	N	3.6	0.24	N
	July	0.4	0.03	N	1.9	0.14	N	1.6	0.12	N
	Oct.	0	0	N	12.5	0.81	N	17.7	1.12	M
	Jan. April	35.9	2.26	S	6.0	0.40	N	0	0	N
106	April	0	0	N	0.8	0.05	N	2.0	0.13	N
	July	0.1	0.01	N	2.4	0.16	N	3.3	0.23	N
	Oct.	0	0	N	11.4	0.75	N	8.6	0.58	N
	Jan. April	0	0	N	5.2	0.34	N	10.0	0.65	N
108	April	0	0	N	0.7	0.05	N	1.2	0.08	N
	July	0.3	0.02	N	6.8	0.47	N	2.0	0.14	N
	Oct.	1.2	0.08	N	11.7	0.77	N	11.7	0.78	N
	Jan. April	0	0	N	3.8	0.26	N	9.3	0.60	N
112	April	0	0	N	0.2	0.01	N	0.7	0.05	N
	July	0.8	0.06	N	2.1	0.15	N	1.4	0.10	N
	Oct.	0	0	N	8.0	0.51	N	6.1	0.39	N
	Jan. April	0	0	N	3.8	0.24	N	6.8	0.44	N

(continued)

TABLE A5 (continued)

Site No.	EXPOSURE PERIOD 1976/1977	ATMOSPHERIC (ACI)			MARINE (MCI)			INDUSTRIAL (ICI)		
		Wt. Loss (mg)	%	Rating*	Wt. Loss (mg)	%	Rating	Wt. Loss (mg)	%	Rating
115	April									
	July	0.3	0.02	N	1.6	0.11	N	1.8	0.12	N
	Oct.	0.8	0.06	N	74.4	5.13	MS	1.7	0.12	N
	Jan.	0.1	0.01	N	4.9	0.31	N	5.0	0.32	N
118	April	0.2	0.01	N	5.3	0.27	N	4.9	0.34	N
	July	0.5	0.04	N	2.2	0.15	N	2.0	0.13	N
	Oct.	0	0	N	2.3	0.17	N	1.1	0.08	N
	Jan.	0	0	N	4.7	0.31	N	6.2	0.40	N
120	April	0	0	N	4.3	0.28	N	4.1	0.27	N
	July	1.0	0.07	N	1.1	0.08	N	1.8	0.13	N
	Oct.	0.3	0.02	N	2.4	0.15	N	1.6	0.11	N
	Jan.	0.4	0.03	N	6.6	0.44	N	9.1	0.59	N
122	April	0	0	N	2.9	0.18	N	0	0	N
	July	0	0	N	1.3	0.09	N	1.9	0.14	N
	Oct.	0	0	N	5.5	0.36	N	2.5	0.17	N
	Jan.	0	0	N	3.5	0.23	N	2.2	0.14	N

*N = Negligible
M = Moderate
S = Severe
MS = Moderately Severe
VS = Very Severe

TABLE A6
AVERAGE CLIMAT VALUES FOR FOUR QUARTERS

Site No.	ACI		MCI		ICI	
	Wt. Loss (mg)	%	Wt. Loss (mg)	%	Wt. Loss (mg)	%
103	0.4	0.02	12.6	0.88	10.9	0.68
105	12.1	0.77	5.5	0.37	7.6	0.49
106	0.1	0.01	5.0	0.32	6.0	0.40
108	0.8	0.05	5.8	0.39	6.0	0.40
112	0.8	0.06	3.5	0.20	3.5	0.24
115	0.4	0.02	21.6	1.46	3.4	0.22
118	0.5	0.04	3.4	0.23	3.4	0.22
120	0.6	0.04	3.2	0.21	4.2	0.28
122	0	0	3.4	0.23	2.2	0.15